Environment Canada

Environnement Canada

Ontario Ministry of the Environment

STANDARDS DEVELOPMENT BRANCH OMOE
36936000006381

Chemical Dosage Control for Phosphorus Removal Research Report No.4

earch Program for the Abatement of Municipal Pollution under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality

Research Report No. 4 Chemical Dosage Control for Phosphorus Removal

TD
758.5
.P56
C44
1974
MOE

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement of Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

The Scientific Liaison Officer for this project was Mr. J. W. Rupke, Ontario Ministry of the Environment.

Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre,
Canada Centre for Inland Waters,
Environment Canada
P. O. Box 5050
Burlington, Ontario. L7R 4A6

Ontario Ministry of the Environment,
Pollution Control Branch,
135 St. Clair Avenue West,
Toronto, Ontario. M4V 1P5.

TD
758.5
.P56
C44
1974

Chemical dosage control for
phosphorus removal /

78487

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

CHEMICAL DOSAGE CONTROL FOR PHOSPHORUS REMOVAL

by

Pollutech Pollution Advisory Services Ltd.

Oakville, Ontario

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY.

Project No. 72-5-11

March, 1973

This document may be obtained from

Training and Technology Transfer
Division (Water)
Environmental Protection Service
Environment Canada
Ottawa, Ontario
KIA OH3

Ontario Ministry of the Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario
M4V 1P5

REVIEW NOTICE

This report has been reviewed by the Technical Committee of the Canada-Ontario Agreement on Great Lakes Water Quality and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of either the Ontario Ministry of the Environment or Environment Canada, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This project was undertaken to determine whether a simple monitoring procedure could be utilized to control chemical addition in municipal waste treatment plants. It was intended to demonstrate that proportional control of chemical feeding would be economically advantageous and to determine which specific parameters could be monitored to enable chemical dosage control and at which locations within a treatment plant.

A review of all available information on chemical dosage control programs underway in the United States was made, and data from the Ontario Ministry of the Environment based on observations at treatment plants were analysed in detail. No data were found upon which chemical dosages and phosphorus residuals could be compared with other related wastewater parameters. Bench-scale jar studies and measurements at a full-scale plant during chemical addition were therefore conducted to obtain the necessary data.

The jar-test studies demonstrated that the chemical dosage required for a 1 mg/l phosphorus residual can be predicted when jar tests are repeated on the same waste sample, and that potential savings in chemicals of 30-40% could theoretically be achieved if a controller capable of measuring chemical requirements to the same accuracy as the jar test could be developed. However, no correlations could be established between the common wastewater parameters in raw sewage and phosphorus concentrations, or the amount of chemical required to achieve a 1 mg/l phosphorus residual. Neither could any positive correlation be established between the common wastewater parameters, measured after chemical addition and rapid mixing, and phosphorus residual.

Observations taken at a full-scale treatment plant at various sampling points during chemical addition revealed a reasonable correlation between final effluent phosphorus and soluble phosphorus in the aeration tank effluent after chemical addition, i.e., limiting the aeration tank effluent soluble phosphorus concentration to 0.2 mg/l, would be expected to result in a 1 mg/l phosphorus residual in the final effluent 80% of the time. It was postulated that the observed phosphorus removal takes place in three

distinct steps with the majority being removed in the aeration tank. This observation can be extended to postulate that phosphorus must be removed in the aeration tank by aluminum hydroxide. It was found that the addition of alum to mixed liquor results in the immediate precipitation of a fairly constant percentage of the soluble phosphorus, but this immediate percentage is almost independent of the chemical dosing rate. Increasing the dosing rate causes an eventual increase in the amount of phosphorus removed by the system.

Rapid on-line control of phosphorus based on phosphorus residuals in the aeration tank effluent, either before or after chemical addition, does not appear feasible. Automatic control of chemical addition based on final effluent phosphorus is technically feasible although such a controller would have to be heavily damped.

In the treatment plant observed, a sudden increase in the dosing rate did not immediately affect the aluminum hydroxide concentration. The concentration increased slowly, which resulted in an eventual improvement in the final effluent quality. The system was thus shown to be strongly self-regulatory and the possibility exists that adequate control might be achieved by manual adjustment of dosing rates a fiw times a day, subsequent to phosphorus measurements in the final effluent. This is only a very tentative inference and it is recommended that further work be undertaken to confirm this impression.

RÉSUMÉ

On a entrepris cette étude pour déterminer s'il était possible d'utiliser une méthode simple de contrôle pour régler l'addition de produits chimiques dans les usines municipales de traitement des eaux usées. On voulait démontrer qu'un réglage proportionnel de l'alimentation en produits chimiques serait économiquement avantageux et déterminer quels paramètres spécifiques conviendraient cette fin et quels endroits de l'usine de traitement se prêteraient à l'application du procédé.

On a examiné toute l'information disponible sur les programmes de réglage de l'addition de substances chimiques qui se poursuivent aux États-Unis et on a analysé dans le moindre détail les données recueilles par le ministère de l'Environnement de l'Ontario à partir d'observation effectuées dans des usines de traitement. On n'a trouvé aucune donnée grâce à laquelle on aurait pu comparer l'addition de quantités de produits chimiques et le phosphore résiduel avec d'autres paramètres communs des eaux usées. On a donc effectué des études en laboratoire et des mesures en usine afin d'obtenir les données nécessaires.

Les tests en laboratoire ont montré, quand its étaient effectués sur le même échantillon d'eaux usées, qu'on peut prédire quelle sera la quantité de produits chimiques nécessaire pour obtenir une concentration en phosphore résiduel de 1 mg/l, et qu'on pourrait théoriquement obtenir une économie en produits chimiques de l'ordre de 30 à 40 p. 100 s'il était possible de mettre au point un appareil de contrôle capable de mesurer les demandes en produits chimiques avec l'exactitude atteinte en laboratoire. Cependant, on n'a pu établir aucune corrélation entre les paramètres communs des eaux usées non traitées et les concentrations en phosphore ou les quantités de produits chimiques nécessaires à l'obtention d'un résidu de phosphore d'une concentration de 1 mg/l. On n'a pas non plusétablir de corrélation sûre entre les paramètres communs des eaux usées, mesurés après une addition de produits chimiques suivie d'un mélange rapide, et le phosphore résiduel.

Les observations faites dans une usine de traitement et à différents points d'échantillonnage pendant l'addition de produits chimiques ont indiqué

une assez bonne corrélation entre le phosphore de l'effluent final et le phosphore soluble présent dans l'effluent du bassin d'aération après l'addition de produits chimiques. En d'autres mots, le fait de limiter à 0.2 mg/l la concentration en phosphore soluble de l'effluent du bassin d'aération devrait amener dans 80 p. 100 des cas une concentration en phosphore résiduel de 1 mg/l dans l'effluent final. On a supposé que l'élimination du phosphore se faisait en trois étapes distinctes, la plus grande partie de la déphosphoration se produisant dans le bassin d'aération. À partir de là, on peut supposer que l'élimination du phosphore devrait se faire par addition d'hydroxyde d'aluminium dans le bassin d'aération. On a observé que l'addition d'alum à la liqueur mixte amenait une précipitation immédiate d'un pourcentage assez constant de phosphore soluble, mais que ce pourcentage était pratiquement indépendant du taux d'addition du produit chimique. Éventuellement, l'augmentation de ce taux mène à un rendement plus grand dans l'élimination du phosphore par le système.

Il semble impossible de réduire rapidement la quantité de phosphore par action sur le traitement en se basant sur la teneur en phosphore résiduel de l'effluent du bassin d'aération, que ce soit avant ou après l'addition de produits chimiques. Il est techniquement possible de régler automatiquement l'addition de produits chimiques en fonction du phosphore de l'effluent final, mai il faudrait régler le systeme de façon à ce qu'il ne réagisse pas trop brusquement.

Les observations effectuées à l'usine de traitement ont montré que le système était hautement autor-régulateur et qu'il réglage serait possible d'arriver à convenable ajustant manuellement les taux d'addition quelques fois par journée, après avoir mesureé la teneur en phosphore de l'effluent final. Ceci n'est qu'une déduction qu'il faudrait confirmer par des travaux plus approfondis.

TABLE OF CONTENTS

		page
ABSTRACT		i
TABLE OF CONTENTS		v
	List of Tables	vi
1	INTRODUCTION	1
1.1	Purpose	1
1.2	Approach	1
2	OBSERVATIONS AND INTERPRETATIONS - PHASE I	3
3	OBSERVATIONS AND INTERPRETATIONS - PHASE II	4
3.1	Reliability of Jar Test Procedures	4
3.2	Significance of Optimizing Chemical Dosage	5
3.3	Search for Control Parameters	6
3.3.1	Correlations Between Phosphorus and Wastewater Parameters	7
3.3.2	Correlation Between Common Wastewater Parameters and The Amount of Aluminum Required to Achieve 1 mg/l Phosphorus Residuals	8
3.3.3	Investigation of the Possible Application of Wastewater Parameters in Feedback Control	9
4	OBSERVATIONS AND INTERPRETATIONS - PHASE III	12
4.1	Approach	12
4.2	Results, Observations and Discussion	13
5	CONCLUSIONS	16
REFERENCES		18
ABBREVIATIONS		19
APPENDIX I -	TABLES AND FIGURES	21
APPENDIX II -	CALCULATION OF CHEMICAL REQUIREMENTS	73
APPENDIX III -	ANALYTICAL METHOD FOR PHOSPHORUS DETERMINATION	77

LIST OF TABLES

TABLE		page
1	Results of Tests to Determine Reproducibility of Jar Test Results	23
2	Turbidity during Rapid Mix as a Function of Aluminum Dosage	24
3	Turbidity After Chemical Addition and ½ Hour of Quiescent Settling (JTU)	25
4	Total Aklalinity as a function of Aluminum Dosage	26
5	Aluminum Concentration in Wastewater Following Chemical Dosing with Aluminum	27
6	pH as a Function of Aluminum Dosage	28
A1	Sample Calculation (Chemical Requirements)	

Chapter 1

INTRODUCTION

Plans to implement a program of nutrient removal in municipal waste treatment plants have been underway in Ontario for the past two years. In almost all cases, some means of chemical addition and precipitation of phosphate-laden wastewaters will be utilized. In any process involving chemical addition, where there are fluctuations in the levels of the components taking part in the reaction, it may be desirable for economic reasons to control the rate of chemical dosage in a manner proportional to the demand. At present there is no means available for controlling chemical addition in municipal treatment plants in order that a minimum of chemical can be used while maintaining the objectives for effluent levels of phosphorus. POLLUTECH, therefore proposed in early 1972 that research should be conducted in this area. Accordingly, we were authorized by mid-1972 to proceed with this project, "Chemical Dosage Control for Phosphorus Removal", as an applied research project under the Canada-Ontario Agreement on Great Lakes Water Quality.

1.1 Purpose

It was the purpose of this project to determine if some simple monitoring procedure could be utilized to control chemical addition in municipal waste treatment plants. It was necessary first to demonstrate that proportional control of chemical feeding would provide an advantage. Further, it was required to determine which specific parameters could be monitored to enable chemical dosage control and at which locations within the treatment plant.

1.2 Approach

The following is an outline of the procedure used in gathering information for this program:

PHASE I

(i) Extensive evaluation of published literature and personal contacts in order to assess other efforts toward this objective.

(ii) Examination of data available from the Ontario Ministry of the Environment to determine if correlations existed between common wastewater parameters and chemical dosages.

PHASE II

(i) Statistical data was examined to demonstrate the reliability of jar test information.

(ii) The significance of dosage control in minimizing chemical costs was calculated.

(iii) Jar testing to determine whether correlations exist between phosphorus concentration and other wastewater parameters such as turbidity, hardness, pH, alkalinity and conductivity.

(iv) Jar testing to determine whether correlations exist between the common wastewater parameters and the amount of aluminum required to achieve a 1 mg/l residual. This step was restricted to those parameters for which rapid analytical procedures were available.

(v) Jar testing to determine whether correlations exist between low levels of residual phosphorus and other simpler parameters.

PHASE III

(i) Observations at a full-scale treatment plant to develop correlations between phosphorus parameters at various points in the plant with chemical addition.

(ii) Prediction, if possible, of the effect of various modes of control on the performance of the system.

Chapter 2

OBSERVATIONS AND INTERPRETATIONS

PHASE I

A thorough review was made of all available information on chemical dosage control programs underway in the United States. Two references were found (1,2) in which phosphorus concentration and wastewater flow were measured and chemical feed rate was adjusted in proportion to the product of flow and concentration. No information was found on any attempts to correlate other wastewater parameters to chemical requirements for phosphorus removal. In addition, it was not possible to find sufficient data for natural waste treatment measurements to obtain any correlation of parameters.

Data available from the Ontario Ministry of the Environment from observations at treatment plants were analyzed in detail. Most of these data were based on jar study results which showed chemical dosages and phosphorus residuals. Other parameters were not measured at the same time however, and therefore no correlations with dosage requirements could be made.

It was apparent at this stage that data did not exist which would allow chemical dosages and phosphorus residuals to be compared with other common wastewater parameters. Therefore, this study proceeded to obtain the necessary data through bench-scale jar studies, as well as measurements at a full-scale plant during chemical addition.

Chapter 3

OBSERVATIONS AND INTERPRETATIONS

PHASE II

3.1 Reliability of Jar Test Procedures

Although jar testing procedures have been used for many years in the evaluation of chemical dosages for water treatment, it is only recently that this technique has been applied to precipitation reactions in wastewater treatment (3). A standard procedure has been set out by the Ontario Ministry of the Environment (4) for a preliminary determination of the chemical to be used and the probable dosing rate at each treatment plant. However, since the objective of this project was to utilize the jar testing procedure to obtain a correlation with other wastewater parameters rather than to select the optimum chemical and the optimum dosage, we proceeded to evaluate the statistical reliability of the jar test procedure for this application.

The standard jar test procedure involves stirring, at 100 rpm, several jars containing 1 litre of sample and appropriate amounts of chemical. After 5 minutes, the stirring rate is decreased to 25 rpm and mixing is continued at this rate for 15 minutes. Quiescent settling is then permitted for 30 minutes and a sample of the supernatant removed for analysis.

On-site jar studies for this phase of the work were conducted at the Town of Acton Water Pollution Control Plant. This treatment plant is a small activated sludge plant of one-half million gallons per day capacity, which serves a primarily residential community. The jar tests were carried out on both raw sewage and secondary effluent. Alum was the only chemical used in this phase of the study. A preliminary series of experiments was conducted to establish the reproducibility of the prescribed jar test procedure.

A series of five jar tests was done on three alum dosages for a typical sewage sample. Table 1, Appendix 1, shows the probable variation in residual phosphorus concentration to be plus or minus 10-15% at the 95% level of confidence.

In order to estimate the dosage requirement to meet a discharge objective of one mg/l the following procedure was used:

All phosphorus concentrations determined from the jar studies were plotted on semilog paper versus the amount of aluminum added, and the best straight line was fitted to these points by the least squares procedure. Hence for each set of jar tests the line could be extrapolated to determine the chemical dosage required to achieve one mg/l of phosphorus residual. The results of all five sets of data at each of three chemical dosages are tabulated in Table 1.

By fitting curves on each of the five sets of data on Figure 1, a comparison was obtained of the chemical dosage prediction from each test sequence. These results show the range of chemical dosage required in order to produce a one mg/l phosphorus residual on the basis of five replicate sets of jar test data. The reproducibility of the dosage requirement estimated by this procedure was calculated to be plus or minus 11% at the 95% confidence level.

3.2 Significance of Optimizing Chemical Dosage

If chemical dosage in the waste treatment process can be continuously varied in order to maintain a one mg/l phosphorus residual, then the minimum possible usage of chemical should result. Of course, minimum usage of chemical is proportional to costs, and therefore implies minimum cost. In order to show the order of magnitude of savings that could result from 'perfect' control of chemical addition, calculations were made of the following:

- Chemical addition proportional to the flow-rate of sewage only.
- Chemical addition proportional to the mass flow-rate of phosphorus in the raw sewage (i.e., proportional to the product of phosphorus concentration and sewage flow-rate). This is equivalent to chemical dosage at a constant aluminum-to-phosphorus ratio.
- Optimum control of chemical addition, based on the graphical determination of the amount of alum required to produce a one mg/l phosphorus residual on the basis of the jar testing procedure.

In interpreting the results of this procedure, it should be noted that in calculating these results, the assumption was made that the jar testing procedure above is a perfect base line for optimal control of chemical addition. Practical effects such as the influence of recycle of aluminum in biological solids recycling were not taken into account.

These calculations show the relative amounts of chemical required by each of the three methods of chemical addition control as follows:

Method of Control of Chemical Addition	Relative Amount of Chemical Required (mg/l)
Dosing proportional to flow of wastewater	1.39
Dosing proportional to product of wastewater flow and phosphorus concentration	1.28
Perfect dosage control	1.0

These results indicate that large potential savings in chemical costs could be realized if dosage control could be implemented which is as efficient as the jar test procedure was in the test case. It may also be noted that the difference between chemical dosage proportional to raw sewage flow, as opposed to control based on mass flow of phosphorus is relatively small. In many cases, the extra expense of phosphorus determination would not be justified, since on-line analysis and a computer-type form of multiplier would be required. Detailed results and the method of calculation are described in Appendix II.

3.3 Search For Control Parameters

Three approaches were pursued in order to identify parameters which could be used, either individually or in combination, to control chemical dosage for optimum phosphorus removal. They were:

- To conduct measurements of hardness, turbidity, pH conductivity, and alkalinity to determine whether correlations with influent phosphorus concentration exist, so that dependence on an on-line phosphorus analyser might possibly be eliminated.

- To carry out sufficient analytical determinations to attempt correlations of common wastewater parameters with the amount of aluminum required to achieve a one mg/l phosphorus residual. If successful, this technique would permit measurement of the correlating parameter and hence feed-forward control of chemical dosing proportional to this parameter.

- To investigate the possibility of finding a parameter which is indicative of almost complete phosphorus precipitation in order to utilize it in a closed-loop type feedback control system.

3.3.1 Correlations Between Phosphorus and Wastewater Parameters

The standard analytical technique for the determination of phosphorus concentration in wastewater is a tedious and involved procedure and is difficult to automate. Hence, its usefulness as a control parameter for chemical addition to a phosphorus removal process has practical limitations. If a reasonable correlation could be established between phosphorus concentration and some other common wastewater parameter such as turbidity, pH, conductivity, alkalinity or hardness, all of which have relatively straightforward analytical techniques, the objective of proportional control might be more easily accomplished. In the case of possible semi-automatic or manual systems, considerable savings in time and cost could be realized. In addition, any form of automated on-line analyzer would be more simplified in form and therefore more practical in small plant applications.

Grab samples of raw sewage and secondary effluent were analyzed for total phosphorus, orthophosphorus and filtered phosphorus, in addition to turbidity, pH, conductivity, alkalinity, and hardness. These various parameters were plotted in different combinations on Figure 2 through 11 in Appendix 1. These figures indicate that there is no strong correlation between phosphorus and any of the above parameters.

The data obtained from this program were also arranged with respect to both the ratio of orthphosphorus to total phosphorus, and filtered phosphorus to total phosphorus for both raw sewage and secondary effluent. Figure 12 shows a probability distribution of the orthophosphorus to total phosphorus ratios. Similarly, Figure 13 shows a probability distribution for the ratio of filtered phosphorus to total phosphorus. Since both orthophosphorus and filtered phosphorus are much simpler to measure than total phosphorus,

the existence of a reasonable correlation would simplify analytical procedures. Figures 12 and 13 show that the range of scatter, and therefore the usefulness of the correlation, is much better for secondary effluent than for raw sewage.

3.3.2 Correlation Between Common Wastewater Parameters and the Amount of Aluminum Required to Achieve 1 mg/l Phosphorus Residuals

Grab samples of both raw sewage and secondary effluent were analyzed for aklalinity, pH, hardness, turbidy, conductivity, and total phosphorus concentration. Jar tests were then performed on these samples in order to establish whether any of these parameters might affect the chemical requirements for achieving a given phosphorus residual. The required aluminum dose to achieve a 1 mg/l phosphorus residual was obtained by the standard graphical technique described in Section 3.1. These results are plotted for the various combinations of parameters on Figures 14-25. The major inferences which can be drawn from these graphical correlations are:

a. There is no evidence of a reliable correlation between the aluminum dosage required to achieve 1 mg/l phosphorus residual and such common wastewater parameters as alkalinity, pH, hardness turbidity or conductivity in the raw sewage.

b. There appears to be some relationship between the phosphorus concentration in raw sewage and the dosage of aluminum required to achieve a 1 mg/l phosphorus concentration. However, this correlation is not sufficiently strong that its implementation would be an improvement over chemical addition proportional to sewage flow rate.

c. There is no indication of a reasonable correlation between the dosage of aluminum required to achieve a 1 mg/l phosphorus residual and any of the common wastewater parameters for secondary effluent.

d. There is a strong correlation between phosphorus concentration in the secondary effluent and the amount of aluminum required to achieve a 1 mg/l phosphorus residual. This correlation

could be useful for chemical dosage control utilizing a feed-forward mode with tertiary treatment.
It could also be used for feed-forward control in secondary treatment, provided: (i) a correlation can be developed between soluble phosphorus concentration in aeration tank effluent, and;(ii) the aluminum recycled with activated sludge does not have a significant influence on the dosing requirement.

3.3.3 Investigation of the Possible Application of Wastewater Parameters in Feedback Control

The purpose of this sequence of correlations was to determine if some of the wastewater parameters which are simple to measure could provide an indication of almost complete precipitation of phosphorus from wastewater. If this phenomenon could be demonstrated, such measurements would be useful in a feedback type of control for regulating chemical addition to the waste treatment system on the basis of phosphorus concentration in the final effluent, or possibly soluble phosphorus concentration in the mixed liquor after chemical addition.

The following conditions were investigated:

a. Turbidity after chemical addition and flash mixing -

Solubility criteria (5) indicate that the hydroxide ion has an affinity for ferric and aluminum cations similar in "strength" to that of the phosphate ion. Therefore, both cation-phosphate and cation-hydroxide are formed. Previous work (6,7) has shown that the ratio of cation-hydroxide to cation-phosphate influences the turbidity and turbidity removal of wastewater. A change in this ratio as a result of complete phosphorus precipitation could thus conceivably be detected by turbidity measurements. Figures 26A, 26B, show the results of experiments carried out on raw sewage and secondary effluent. These data are also tabulated in Tables 2A and 2B. Aluminum at various dosages was added to the sample and turbidity measurements taken. A change of slope was expected at the point where phosphorus precipitation was nearly complete. Although some change of slope is noticeable in both Figures 26A and 26B, it is not sufficiently distinct,

for control purposes, to warrant additional confirmation.

b. Turbidity after quiescent settling as a control parameter -

Turbidity measurements were taken on the supernatant of a number of jar test samples following 1/2 hour of quiescent settling.

The results of this sequence of experiments are tabulated in Table 3 and indicate a trend of lesser turbidity with increasing aluminum addition. It was observed, however, that there was considerable inconsistency between the various sewage samples measured. Figure 27 shows a plot of turbidity measurements after 1/2 hours of quiescent settling versus residual phosphorus. While this plot does show some correlation, it was not considered a strong enough indication to warrant additional experimentation to determine its usefulness as a control parameter.

c. Alkalinity as a control parameter -

Stoichiometric calculations (8) have determined that a reduction in alkalinity of approximately 4.2 mg (as $CaCO_3$) per mg of aluminum is obtained when precipitation of phosphorus takes place. It is calculated that 5.6 mg alkalinity is removed per mg of aluminum when all phosphorus has been precipitated, and aluminum reacts with hydroxide ion. Since alkalinity determination is a much simpler analytical technique than phosphorus measurement, this phenomenon was pursued to assess its usefulness.

The results of these experiments are tabulated in Tables 4A and 4B and shown graphically on Figures 28A, 28B. The graphical result indicates no change in slope of the alkalinity curve either for raw sewage or secondary effluent after most of the phosphorus has been precipitated. An arrow on the graph indicates the aluminum dosage at a point where precipitation of phosphorus is almost complete. Hence while theoretical stoichiometry indicates that a phenomena should occur, it would appear that other reactions with ions which are common in natural waters may completely mask any such theoretical effect. At any rate, alkalinity was discarded from further consideration as a control parameter for chemical addition.

d. Aluminum concentration as a control parameter -

Under normal conditions the addition of aluminum to wastewater results in precipitation of aluminum-phosphorus compounds. It was thus

expected that, when phosphorus has been completely precipitated, further addition of aluminum would result in some increase in the soluble aluminum concentration. It was hoped that this increase would be in direct proportion to the amount added after all phosphorus had been precipitated. Table 5 shows a tabulation of the data obtained from experiments to determine aluminum concentration in solution as a function of aluminum added.

Aluminum concentrations observed in the unfiltered and undigested samples are probably due to small floc rather than to soluble aluminum. Further, undetectable concentrations in filtered, undigested samples indicate that there is no increase in soluble aluminum concentration on addition of excess aluminum. Thus, even if an excess of aluminum is added over that required to precipitate phosphorus, the excess does not remain in solution but is completely precipitated as a hydroxide. Therefore, aluminum concentration does not appear to have any potential for the control parameter application investigation.

e. pH as a control parameter -

As discussed in subsection d., above, both phosphate and hydroxide cations are known to precipitate with aluminum. Further, it has already been demonstrated experimentally that aluminum does not stay in solution but is precipitated when an excess is added beyond the requirements for phosphorus precipitation. If the failure of aluminum to remain in solution is due to hydroxide precipitation, then the change in hydroxide ion concentration should be measurable as a change in pH and could possibly indicate the equivalent of the excess aluminum addition following precipitation of phosphorus. A sequence of experiments was thus carried out in order to determine if this technique showed any reasonable potential.

The results of these experiments are tabulated in Tables 6A and 6B and plotted on Figures 29A, 29B. These show that although some change in slope of pH curve occurs, there is not sufficient indication of a strong tendency to warrant further investigation into this phenomenon.

Chapter 4

OBSERVATIONS AND INTERPRETATIONS PHASE III

4.1 Approach

The results of the jar studies conducted in Phase II of this investigation showed that any chemical dosage control would have to be based on phosphorus analysis.

The three possible modes of control for chemical dosage prior to secondary clarification are illustrated in Figure 30.

(i) In the first mode the soluble phosphorus concentration in the effluent from the aeration tank is measured before chemical addition and the dosing rate adjusted accordingly. Before this can be done it is necessary to develop a correlation between this soluble phosphorus before chemical addition and the amount of aluminum required to reduce the phosphorus concentration of the final effluent to less than 1 mg/l.

(ii) In the second mode, the soluble phosphorus concentration after chemical addition is measured and the dosing rate increased if the soluble phosphorus increases to above the set point. The dosing rate continues to increase until the residual is again reduced to the predetermined level. For successful implementation, this mode requires a correlation to be developed between this soluble phosphorus concentration after chemical addition and total phosphorus in the final effluent.

(iii) The third mode, which is similar to the second, but based on final effluent phosphorus rather than soluble phosphorus before clarification, requires no such correlation, but suffers from the drawback of the large 'deed' time lag in the secondary clarifier which makes automatic control difficult.

Studies were instituted at a secondary sewage treatment plant equipped with phosphorus removal facilities in order to develop the required correlations and, if possible, to predict the effect of each of these modes of control by dosing proportional to sewage flow rates and observing the variation in phosphorus concentrations at various points in the treatment plant.

The Kitchener Water Pollution Control Plant where this work was carried out is a conventional activated sludge plant, currently treating approximately 15 mgd. The nominal retention time in the aeration tanks at this flowrate is 8 hours and in the secondary clarifiers, approximately 2 hours.

Alum was dosed to the aeration tank effluent proprotional to sewage flow rate, the dosing pump being manually adjusted according to sewage flow every 2 hours.

Samples of aeration tank effluent before and after chemical dosing, and of secondary effluent were collected every 2 hours. The two aeration tank effluent samples were settled, and the supernatant decanted, then filtered. A portion of the secondary effluent sample was filtered and the rest saved for analysis. The four samples were analyzed for total phosphorus.

4.2 Results, Observations and Discussion

The results of the program are shown in Figures 31 to 34. The average retention time in the secondary clarifiers is of the order of 2 hours. To permit direct comparison between aeration tank effluent and final effluent, the final effluent results were moved back 2 hours before the curves were plotted.

The excellent correlation between the filtered aeration tank and filtered final effluent curves demonstrates the validity of this approach. It also shows that there is no further removal of soluble phosphorus in the secondary clarifiers by adsorption.

The large difference between the concentrations of soluble phosphorus in the raw sewage and aeration tank effluent before chemical addition (see Figures 31 to 35) lead to the conclusion that the bulk of the phosphorus removed is precipitated in the aeration tank itself. The only reasonable

explanation for this is that aluminum hydroxide recycled with return sludge is capable of precipitating phosphorus as aluminum phosphate.

To examine the correlation between soluble phosphorus in aeration tank effluent after chemical dosage and total phosphorus in the final effluent, these two parameters were plotted on Figure 36, the best straight line fitted to the data by means of a least squares procedure and confidence limits estimated. The scatter is fairly broad but the correlation is clear. Figure 37 was obtained from this data by considering a small range of residual phosphorus in aeration tank effluent after dosing (e.g., 2-3) and calculating the corresponding percentage of final effluent results which lie below the 1 mg/l level and similarly for the other intervals. This curve shows, for example, that if the phosphorus residual of the aeration tank effluent after final dosing could be controlled at 0.2 mg/l the final effluent total phosphorus concentration would be less than 1 mg/l for 80% of the time. To achieve a 1 mg/l residual for approaching 100% of the time, the soluble phosphorus in the dosed aeration tank effluent would have to be limited to 0.1 mg/l.

Figure 38 is derived from corresponding soluble phosphorus concentrations in the aeration tank effluent before and after dosing, and shows the percent phosphorus removed 'immediately' by precipitation as a function of alum dosage. This figure shows the percent removal to be fairly constant and almost independent of the alum dosage between 35 and 180 mg/l. This is further illustrated in Figure 39, where the soluble phosphorus concentration in the aeration tank effluent before chemical addition is plotted against the difference in concentration before and after dosing. This curve shows theamount of phosphorus removed 'immediately' to be proportional to the soluble phosphorus in the mixed liquor and virtually independent of the alum dosing rate. Figure 40 is a plot of the two-hourly average alum dosage against phosphorus residual in the final effluent and again shows that for the short time period considered (2 hours), phosphorus in the final effluent is independent of dosing rate. Based on these observations, it is postulated that phosphorus removal takes place in three distinct stages:

i) The bulk of soluble phosphorus is precipitated by aluminum hydroxide (and to a greater or lesser extent by absorption on floc particles) in the aeration tank.

(ii) A fairly constant proportion of the residual is precipitated 'immediately' by chemical addition.

(iii) Solid forms of phosphorus are removed by coagulation and clarification.

If this postulation is correct, rapid, on-line control of chemical dosage based on soluble phosphorus in the aeration tank effluent (feed-forward or feedback control) is obviously not feasible.

Feedback control by measurement of total phosphorus in the final effluent is probably technically feasible with a very heavily damped controller, as the two-hour 'dead' time lag in the secondary clarifier becomes unimportant. This point is illustrated as follows:

If the final effluent pnosphorus rises above 1 mg/l, this condition cannot be rapidly corrected by adjusting the dosing rate. A sudden increase in dosing rate will only serve to slowly increase the aluminum hydroxide concentration in the aeration tank which will in due course result in an improvement in final effluent quality. This process obviously occurs very slowly, but does show the system to have a large buffering capacity and hence, it is strongly self-regulatory.

Figure 41 shows daily average dosing rates and final effluent phosphorus concentrations. In Figure 42 these two parameters are plotted for correlation. Again, phosphorus residual appears independent of aluminum dosing rate. This suggests that the response time of the system may be in the order of 24 hours or more and adequate control may be possible by analysing final effluent for total phosphorus once a day or once a shift and adjusting the dosing rate accordingly.

This is only an indirect inference and further work would be required to confirm this impression.

Chapter 5

CONCLUSIONS

The results of the various experiments using jar testing procedures showed that:

1. The prediction of dosage required for a 1 mg/l phosphorus residual is relatively consistant when jar tests are repeated on the same waste sample.

2. Potential savings in chemicals of 30 - 40% over conventional methods of dosing control could theoretically be achieved if a controller capable of measuring chemical requirements to the same accuracy as the jar test could be developed. This portion of the study also produced the observation that control based on phosphorus mass flow would result in an improvement of only some 5 to 6% over a controller governed by waste flow alone.

3. No correlation could be established between the common waste water parameters in raw sewage and phosphorus concentrations.

4. No correlation was found between the amount of chemical required to achieve a 1 mg/l phosphorus residual and the various common wastewater parameters.

5. No positive correlation could be established between the common wastewater parameters measured after chemical additon and rapid mixing, and phosphorus residual, although turbidity measurement showed some possible usefulness.

Following is a summary of the conclusions formed on the basis of observations made at a full-scale treatment plant at various sampling points during chemical addition to the plant:

1. No reliable correlation could be obtained between final effluent turbidity and total phosphorus concentration.

2. A reasonable correlation was indicated between final effluent phosphorus and soluble phosphorus concentration in the aeration tank effluent after chemical addition. Limiting the aeration tank effluent soluble phosphorus concentration to 0.2 mg/l, would be expected to result in a 1 mg/l phosphorus residual in the final effluent 80% of the time.

3. It is postulated that the observed phosphorus removal takes place in three distinct steps with the majority being removed in the aeration tank. This observation can be extended to postulate that phosphate is removed in the aeration tank by aluminum hydroxide.

4. Addition of alum to mixed liquor results in the immediate precipitation of a fairly constant percentage of the soluble phosphorus. The percentage removed immediately is almost independent of the chemical dosing rate. Increasing the dosing rate eventually increases the metal concentration in the aeration tank and hence increases the amount of phosphorus removed by the system.

5. Rapid, on-line control of phosphorus based on phosphorus residuals in the aeration tank effluent, either before or after chemical addition, does not appear feasible.

6. Automatic control of chemical addition based on final effluent phosphorus is technically feasible although such a controller would have to be very heavily damped.

7. The treatment plant observed showed that the system in a control sense was strongly self-regulating and that the possibility exists that adequate control might be achieved by manual adjustment of dosing rates a few times a day, based on to phosphorus measurements in the final effluent. This is only a very tentative inference and it is recommended that further work be undertaken to confirm this impression.

REFERENCES

1) Terence Campbell, Dow Chemical Company, Midland, Michigan, Private Communication (1973)

2) U.S. Environmental Protection Agency, Phosphate Removal in an Activated Sludge Facility, Washington, GPO, (June 1972) (EPA Project #WPRD 247-01)

3) American Waterworks Association, "Simplified Procedures for Water Examination" M 12, p. 42.

4) Ontario, Ministry of the Environment, "Treatability Studies for Phosphorus Removal", Toronto, (April 28, 1972)

5) Mulbarger, M.C., and Shifflett, D.G., "Combined Biological and Chemical Treatment for Phosphorus Removal." Chem. Eng. Progr. Symp. Ser., 107, (1970)

6) Fair, G.M., et al., Water and Waste Water Engineering Vol. II, New York, N.Y. John Wiley and Sons, Inc., (1968)

7) Long, D.A., et al., "Soluble Phosphate Removal in the Activated Sludge Process - & Two Year Plant Scale Study" Paper presented at 26th Ind. Waste Conf., Purdue Univ., Lafayette, Ind. (May, 1971).

ABBREVIATIONS

mg	Milligram
mg/l	Milligram per liter
mgd	Million gallons per day
Al	Aluminum
P	Phosphorus
Ca	Calcium
O	Oxygen
C	Carbon
J.T.U.	Jackson Turbidity Units
WPCP	Water Pollution Control Plant
OME	Ontario Ministry of the Environment

APPENDIX I

TABLES AND FIGURES

TABLE 1. RESULTS OF TESTS TO DETERMINE REPRODUCIBILITY OF JAR TEST RESULTS.

Dosage of Chemical		RUN NUMBER					95% Confidence Units on Total P
		1	2	3	4	5	
	Total P	4.5	4.1	5.17	3.87	4.2	- 4.35 ± 0.493
5 mg/l Al	Filtered P	2.4		2.76	2.32	2.43	
	pH	7.5	7.55	7.45	7.55	7.60	
	Turbidity	21.0	20.0	18.0	18.0	17.0	
	Total P	2.7	2.2	2.5	2.36	1.92	- 2.18 ± 0.344
10 mg/l Al	Filtered P	0.285		0.375	0.51	0.44	
	pH	7.35	7.35	7.35	7.40	7.35	
	Turbidity	20.0	16.0	16.0	16.0	14.0	
	Total P	1.69	1.66	1.56	1.55	1.32	- 1.43 ± 0.24
15 mg/l Al	Filtered P			0.064	0.084	0.104	
	pH	7.20	7.20	7.20	7.20	7.15	
	Turbidity	18.0	16.0	15.0	15.5	13.5	

TABLE 2. TURBIDITY DURING RAPID MIX AS A FUNCTION OF ALUMINUM DOSAGE.

2A. RAW SEWAGE

Aluminum Dosage (mg/l)	Turbidity (JTU)	Total Phosphorus Concentration following Chemical Addition (mg/l)
0	60	11.7
15	85	4.27
20	94	3.13
25	99	2.54
30	100	1.45
35	120	1.69
40	120	1.56

2B. SECONDARY EFFLUENT

Aluminum Dosage (mg/l)	Turbidity (JTU)	Total Phosphorus Concentration following Chemical Addition (mg/l)
0	7	4.7
10	15	1.99
15	18	1.41
20	23	0.39
25	27	
30	38	0.2
35	38	0.2

TABLE 3. TURBIDITY AFTER CHEMICAL ADDITION AND $\frac{1}{2}$ HOUR OF QUIESCENT SETTLING (JTU)

Raw Sewage	Dosage of Aluminum Added (mg/l)							
	5	10	15	20	25	30	35	40
Sample #1	43	42	41	35	29	29		
Sample #2			38	31	30	21	26	26
Sample #3			20	25	28	19	16	

TABLE 4. TOTAL ALKALINITY AS A FUNCTION OF ALUMINUM DOSAGE

4A. RAW SEWAGE

Aluminum Dosage (mg/l)	Total Alkalinity (mg/l as $CaCO_3$)	Total Phosphorus Cencentration following Chemical Addition (mg/l)
0	485	10.56
10	390	6.47
15	345	6.0
20	295	1.05

4B. SECONDARY EFFLUENT

Aluminum Dosage (mg/l)	Total Alkalinity (mg/l) as $CaCO_3$)	Total Phosphorus Cencentration following Chemical Addition (mg/l)
0	560	5.0
15	445	0.92
20	400	0.45
25	370	0.38
30	310	0.38
35	250	0.32
40	220	0.34

TABLE 5. ALUMINUM CONCENTRATION IN WASTEWATER FOLLOWING CHEMICAL DOSING WITH ALUMINUM.

Sample	Amount of Aluminum Added (mg/l)						
	10	15	20	25	30	35	
Unfiltered and Undigested	4.2	4.2	1.5	4.2	1.2	2	
Filtered and Undigested	----Undetectable----						

TABLE 6. pH AS A FUNCTION OF ALUMINUM DOSAGE

6A. RAW SEWAGE

Aluminum Dosage (mg/l)	pH	Total Phosphorus Concentration Following Chemical Addition (mg/l)
0	7.75	11.7
20	7.25	3.13
25	6.95	2.54
30	6.85	1.45
35	6.75	1.67
40	6.5	1.56

6B. SECONDARY EFFLUENT

Aluminum Dosage (mg/l)	pH	Total Phosphorus Concentration Following Chemical Addition (mg/l)
0	7.7	4.7
10	7.5	1.99
15	7.2	1.41
20	6.85	0.39
25	6.75	--
30	6.45	0.2
35	6.35	0.28

FIGURE 1 METHOD FOR DETERMINATION OF AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l RESIDUAL PHOSPHORUS

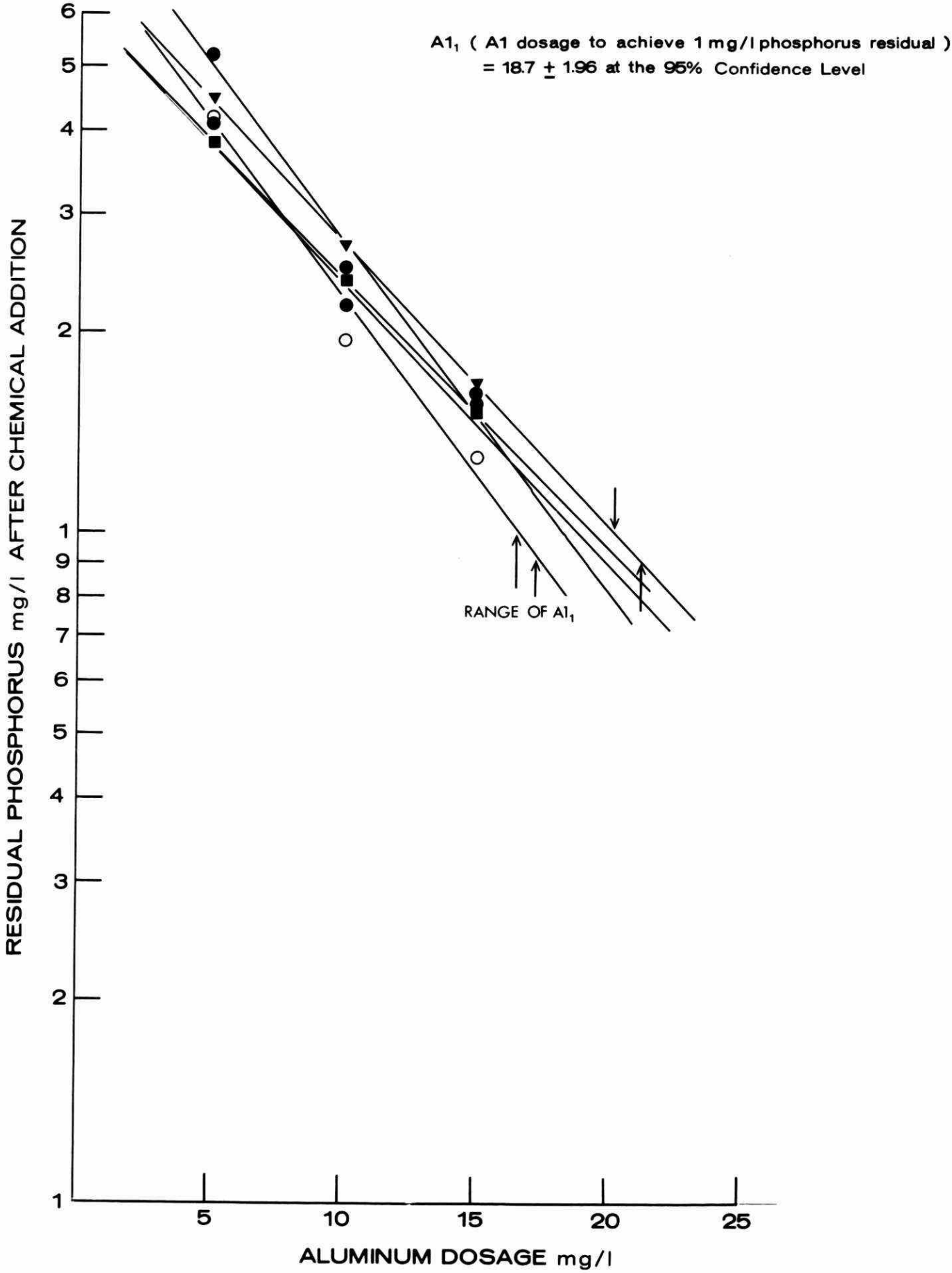


FIGURE 2 PHOSPHORUS CONCENTRATIONS VS pH

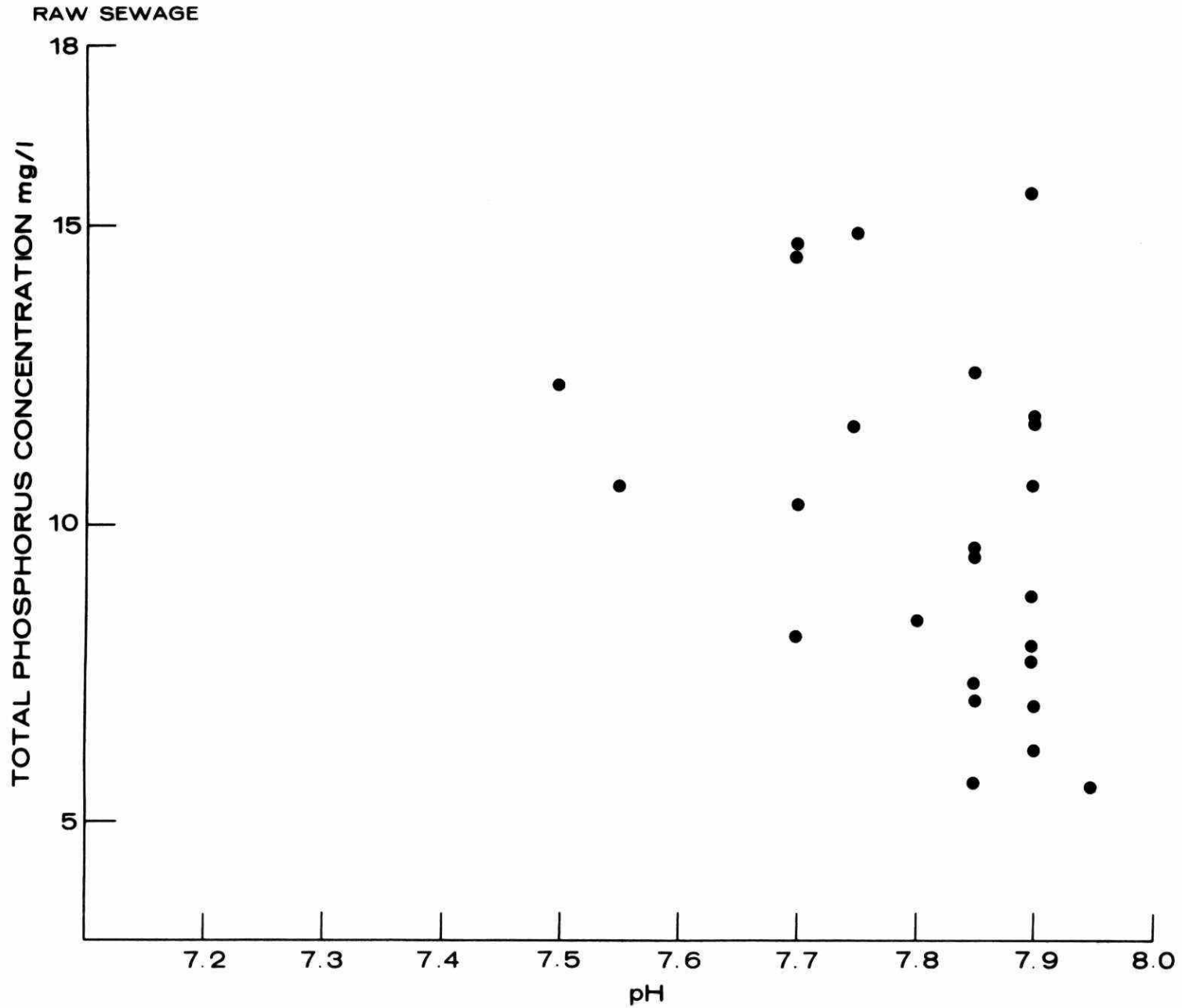


FIGURE 3 PHOSPHORUS CONCENTRATIONS VS TURBIDITY

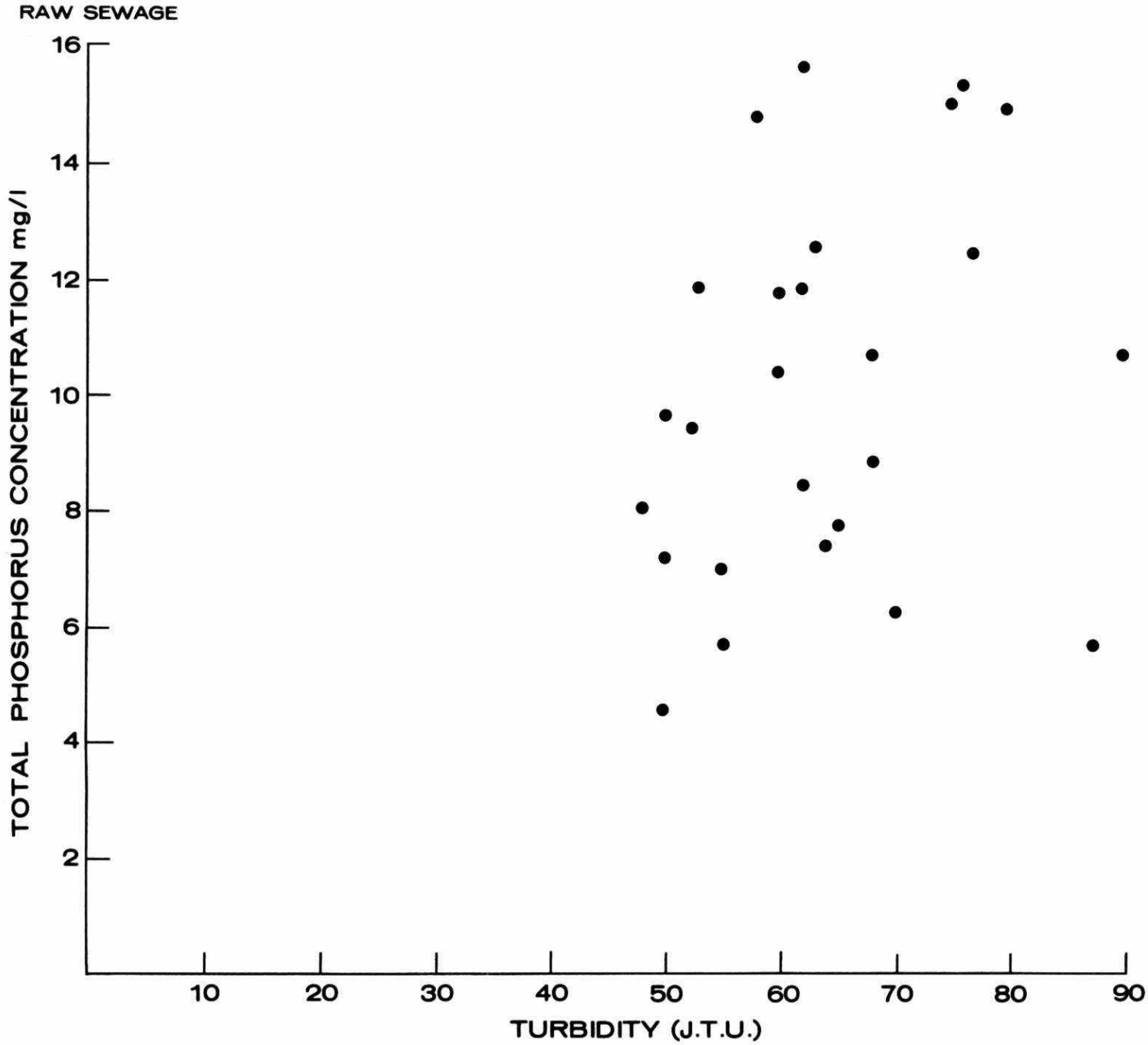


FIGURE 4 PHOSPHORUS CONCENTRATION VS HARDNESS

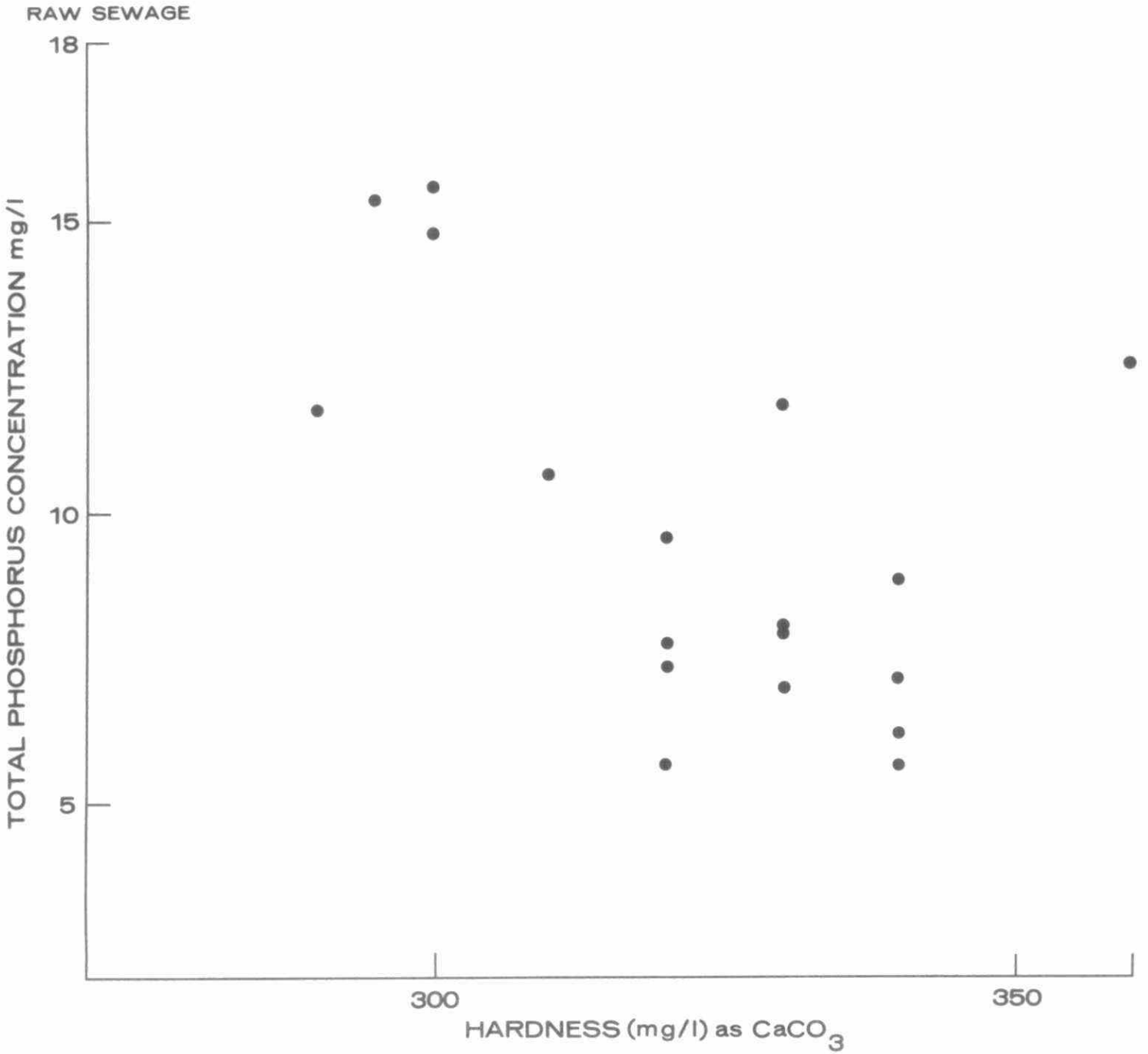


FIGURE 5 PHOSPHORUS CONCENTRATION VS ALKALINITY

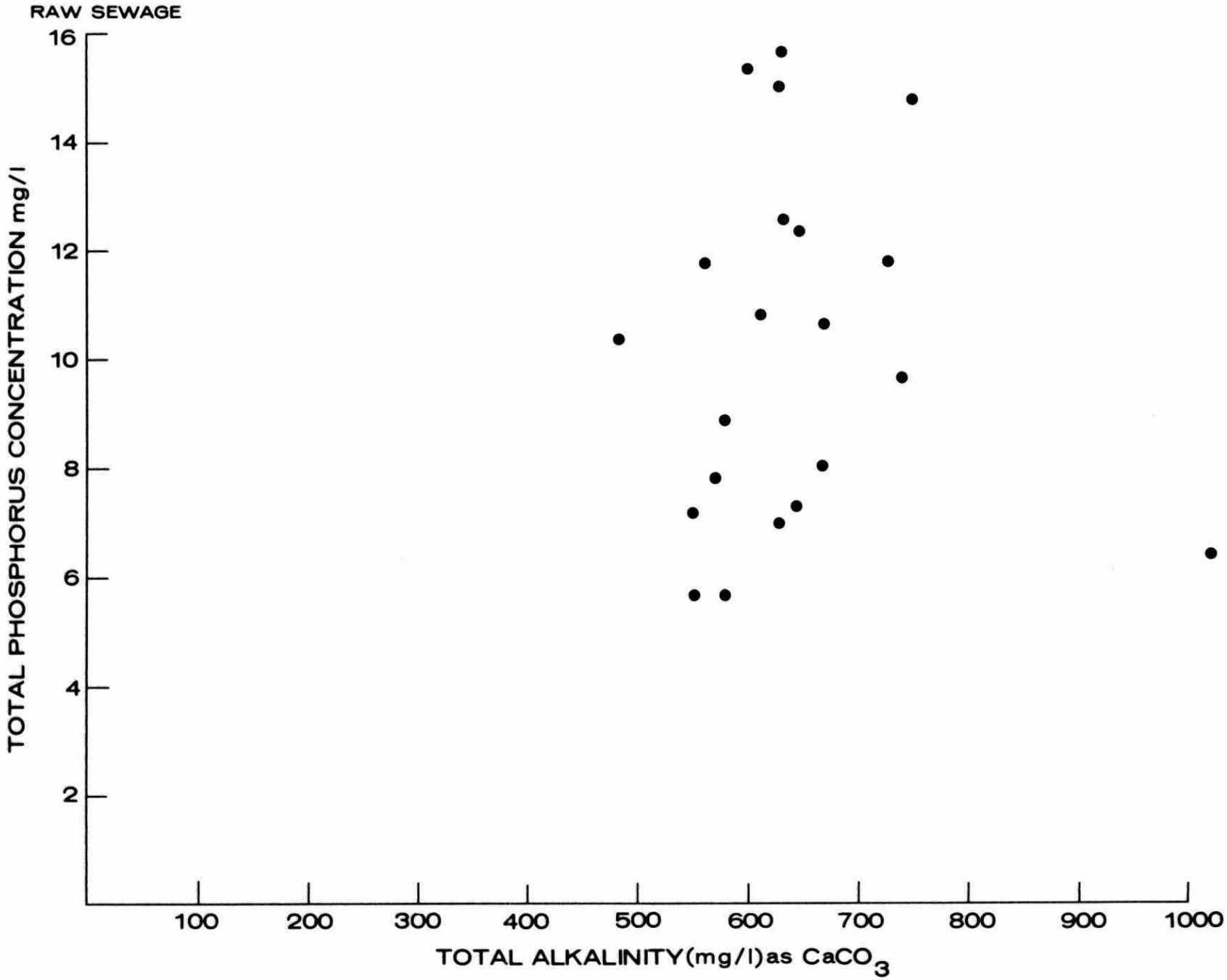


FIGURE 6 PHOSPHORUS CONCENTRATION VS CONDUCTIVITY

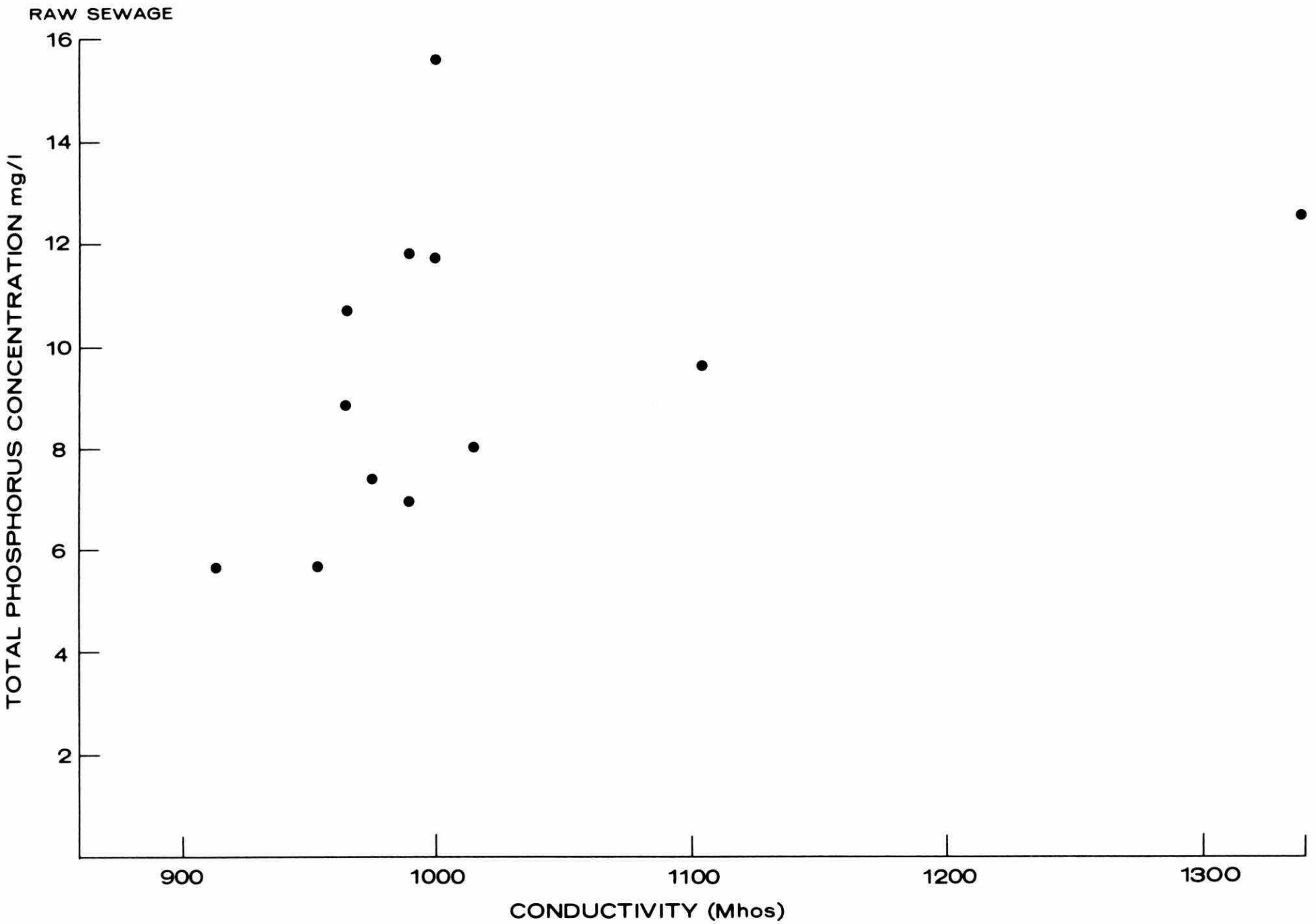


FIGURE 7 PHOSPHORUS CONCENTRATIONS VS pH

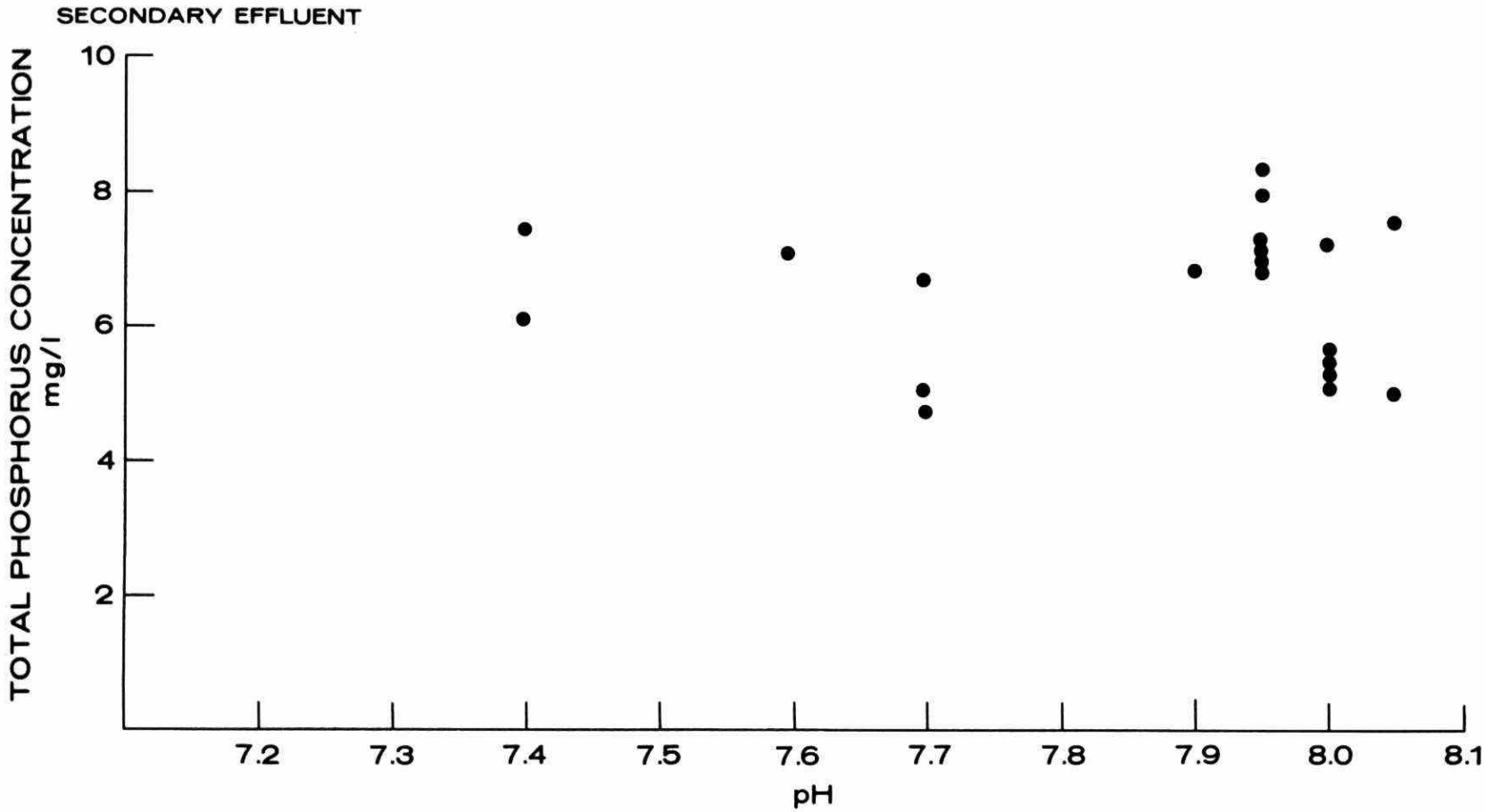


FIGURE 8 PHOSPHORUS CONCENTRATION VS TURBIDITY

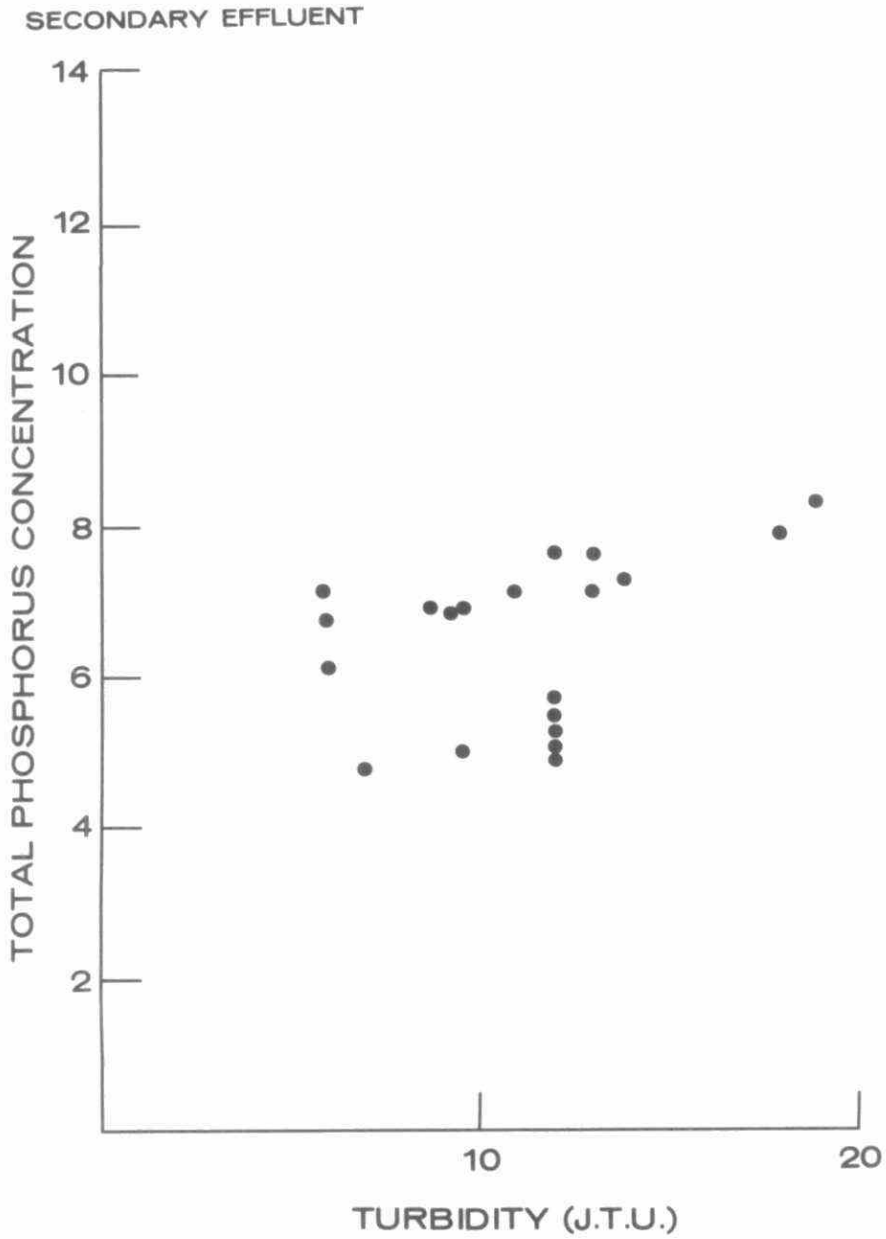


FIGURE 9 PHOSPHORUS CONCENTRATION VS HARDNESS

SECONDARY EFFLUENT:

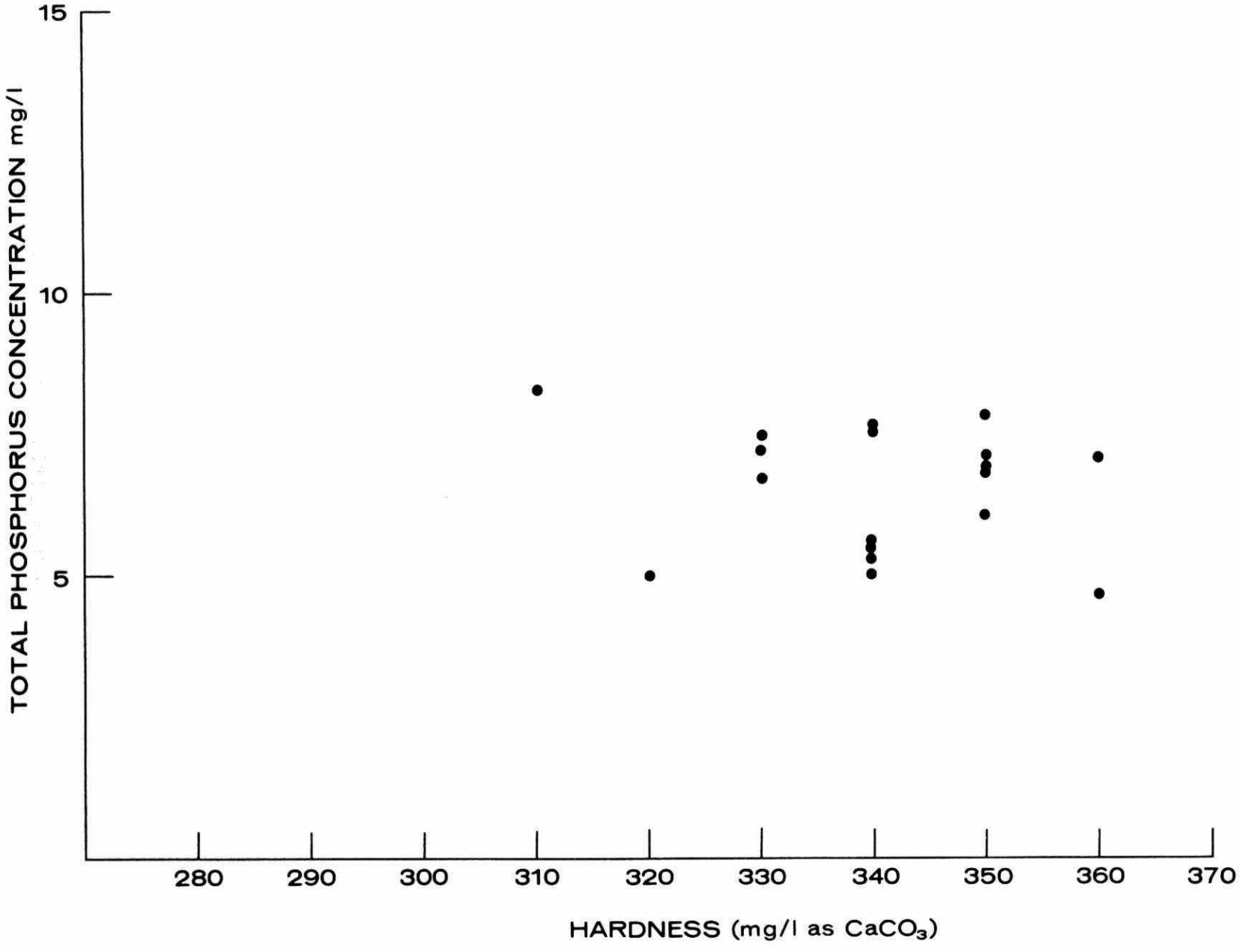


FIGURE 10 PHOSPHORUS CONCENTRATION VS ALKALINITY

SECONDARY EFFLUENT:

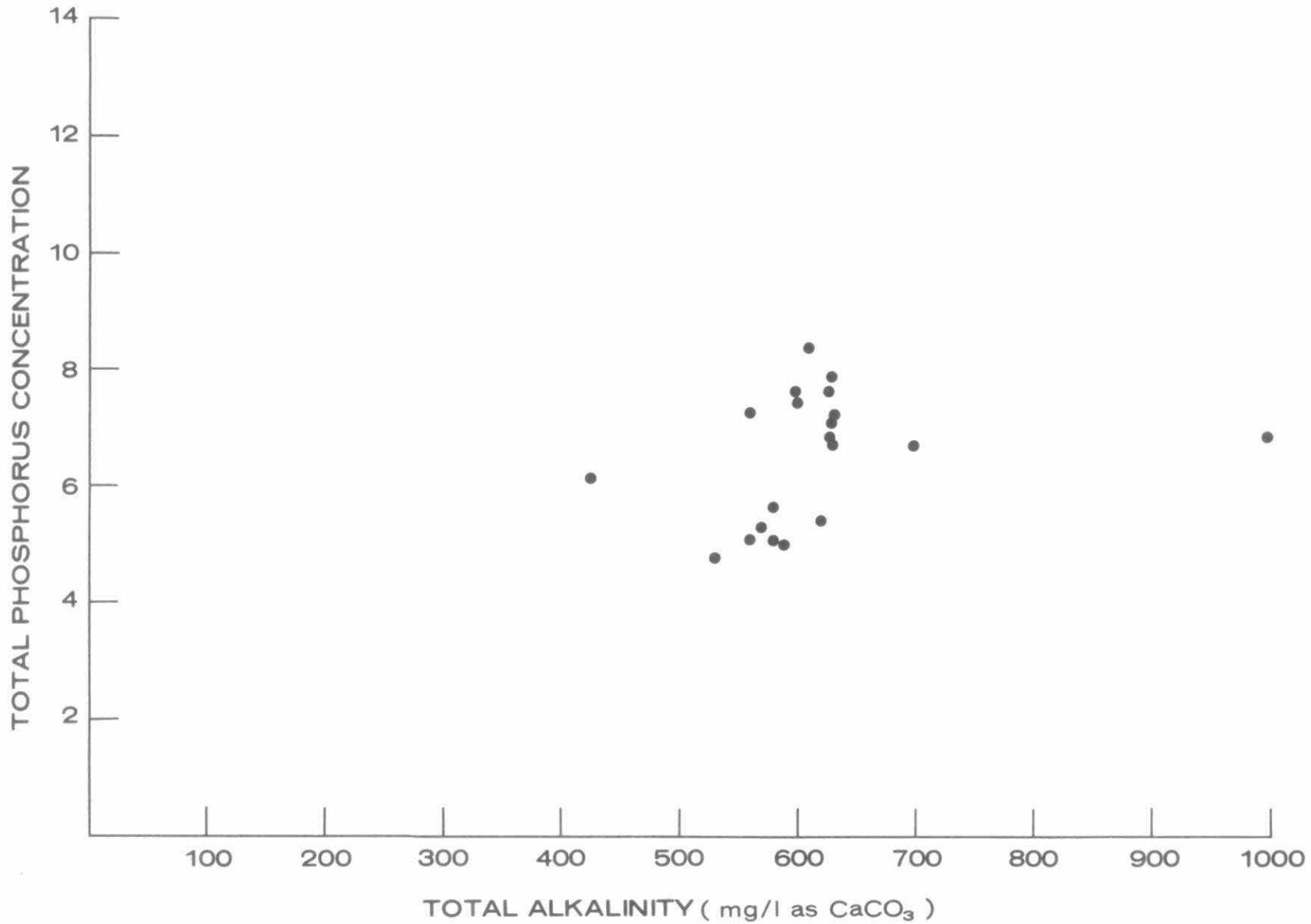


FIGURE 11 PHOSPHORUS CONCENTRATION VS CONDUCTIVITY

SECONDARY EFFLUENT

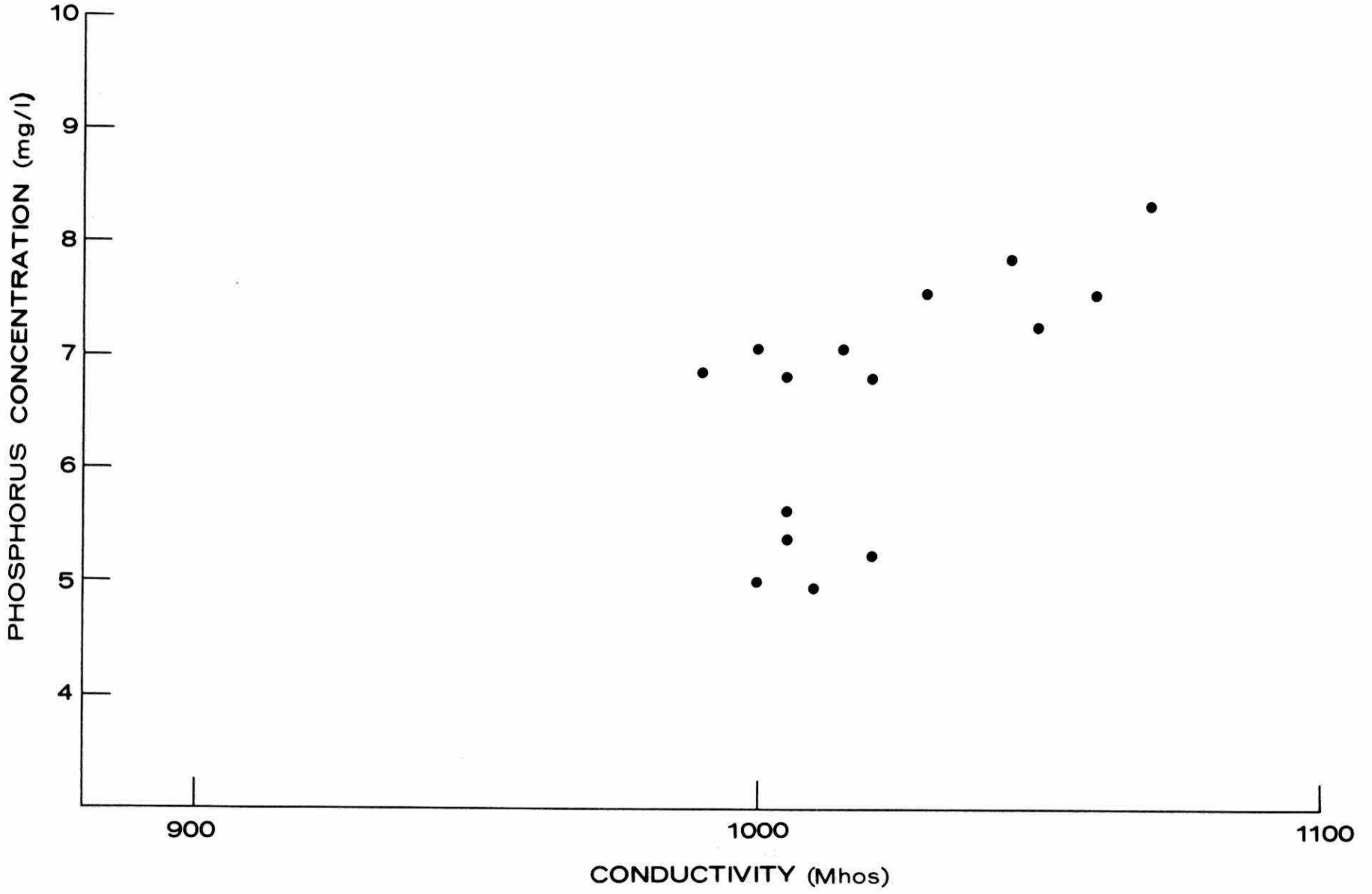


FIGURE 12 RATIO OF ORTHO PHOSPHORUS TO TOTAL PHOSPHORUS CONCENTRATION DISTRIBUTION IN SECONDARY EFFLUENT & RAW SEWAGE

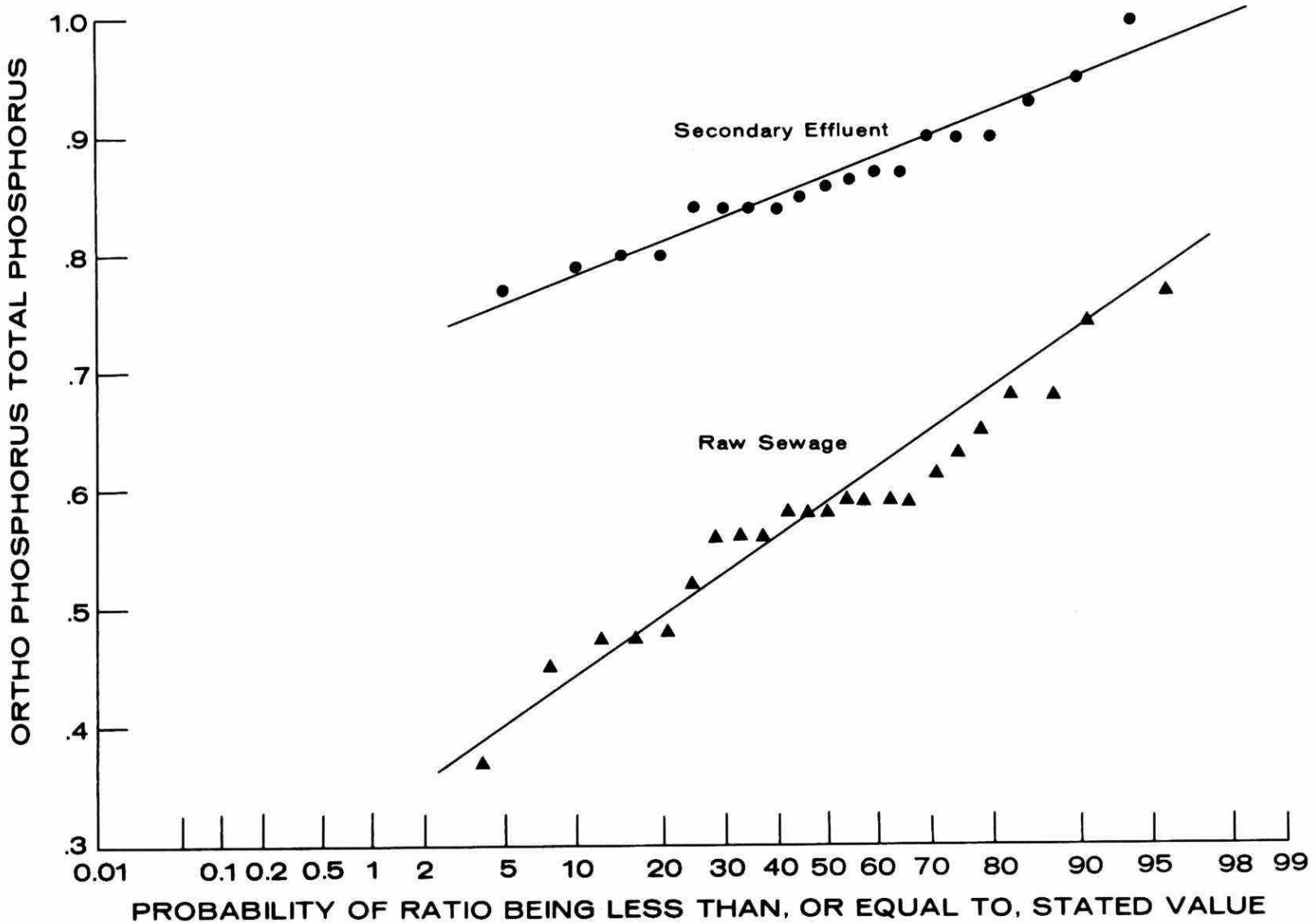


FIGURE 13 RATIO OF PHOSPHORUS CONCENTRATIONS IN FILTERED AND UNFILTERED SAMPLES DISTRIBUTION IN RAW SEWAGE &SECONDARY EFFLUENT

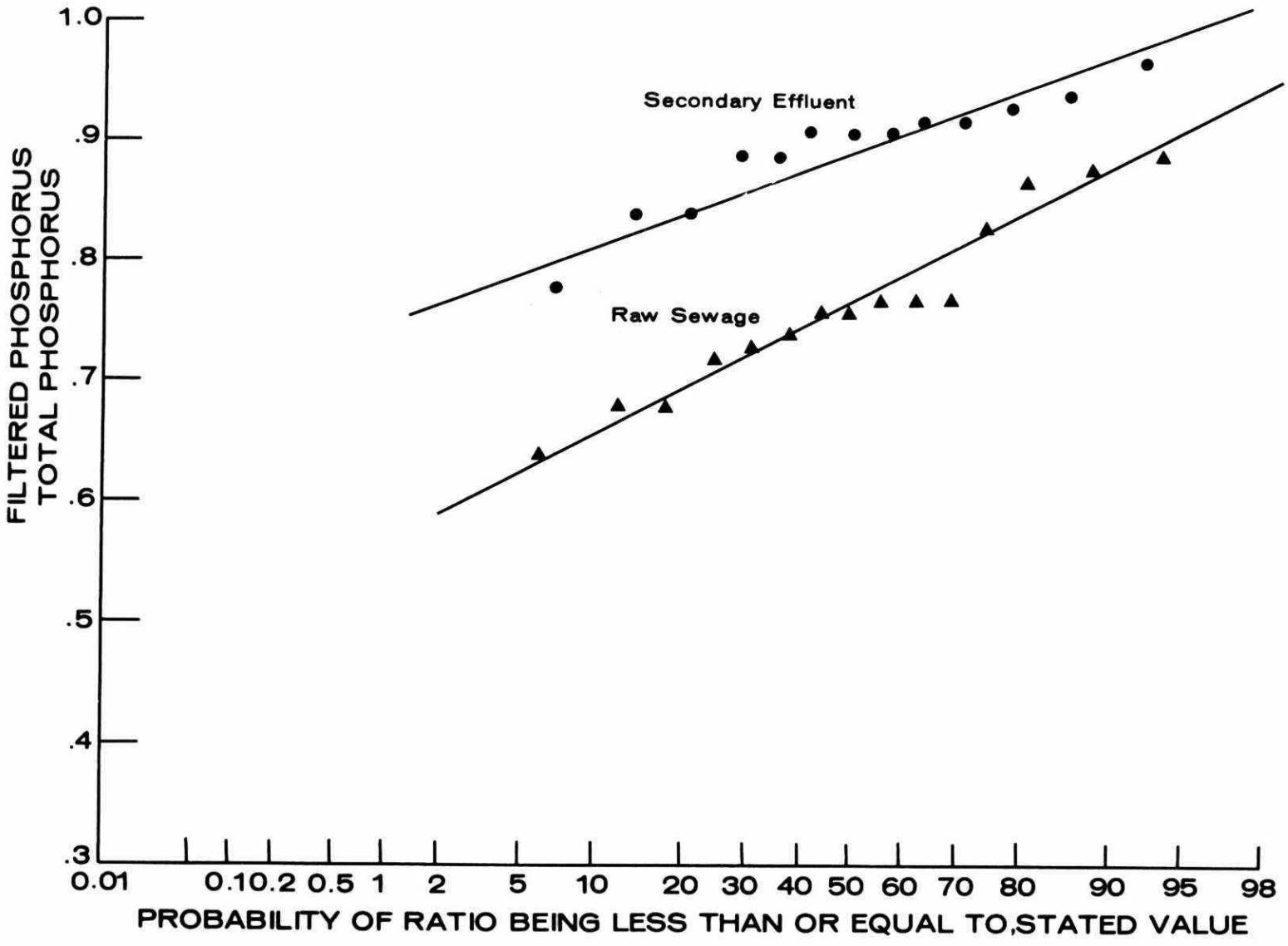


FIGURE 14 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE A 1 ppm PHOSPHORUS RESIDUAL VS pH, BEFORE CHEMICAL ADDITION

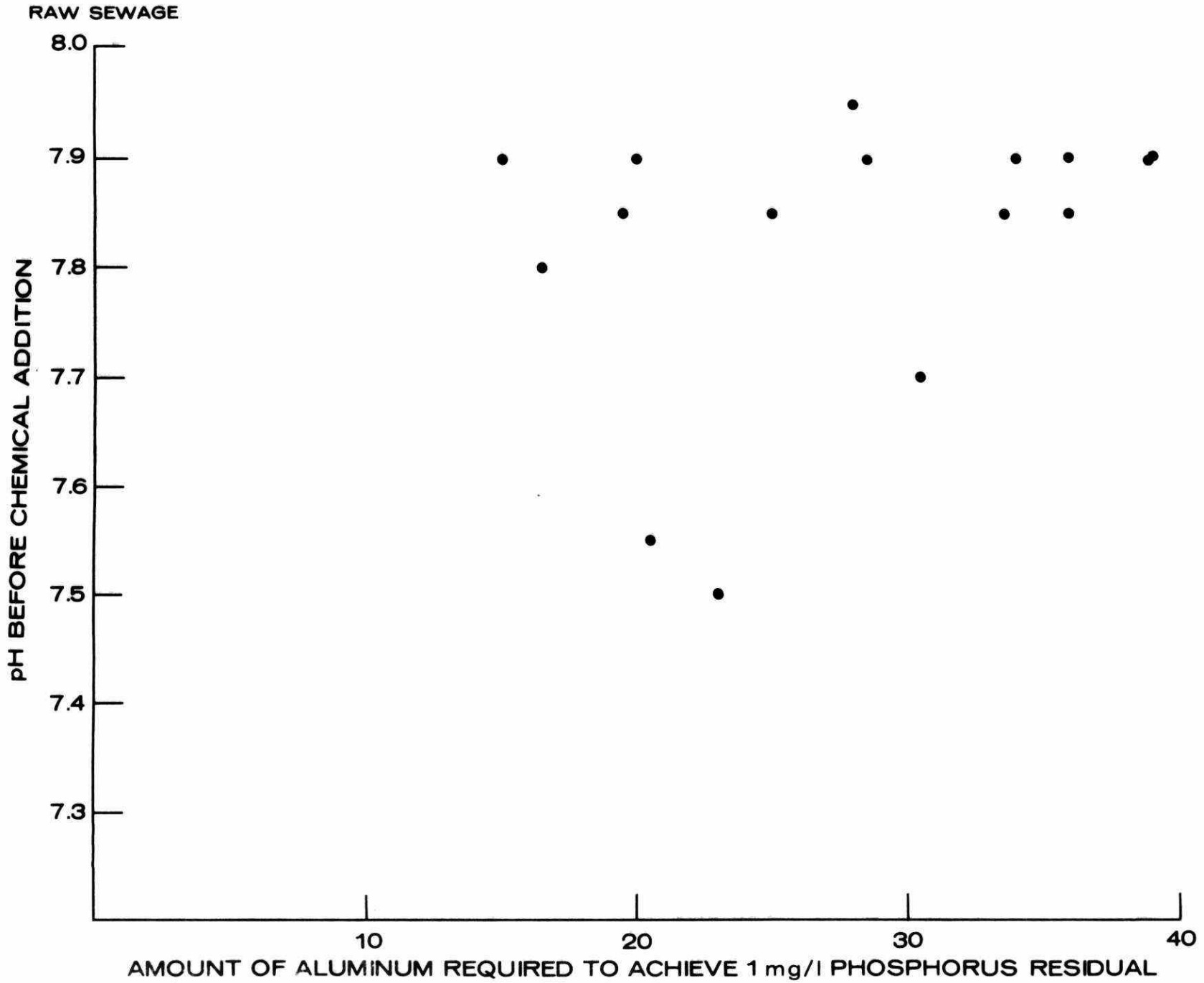


FIGURE 15 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE A 1 ppm PHOSPHORUS RESIDUAL VS ALKALINITY BEFORE CHEMICAL ADDITION

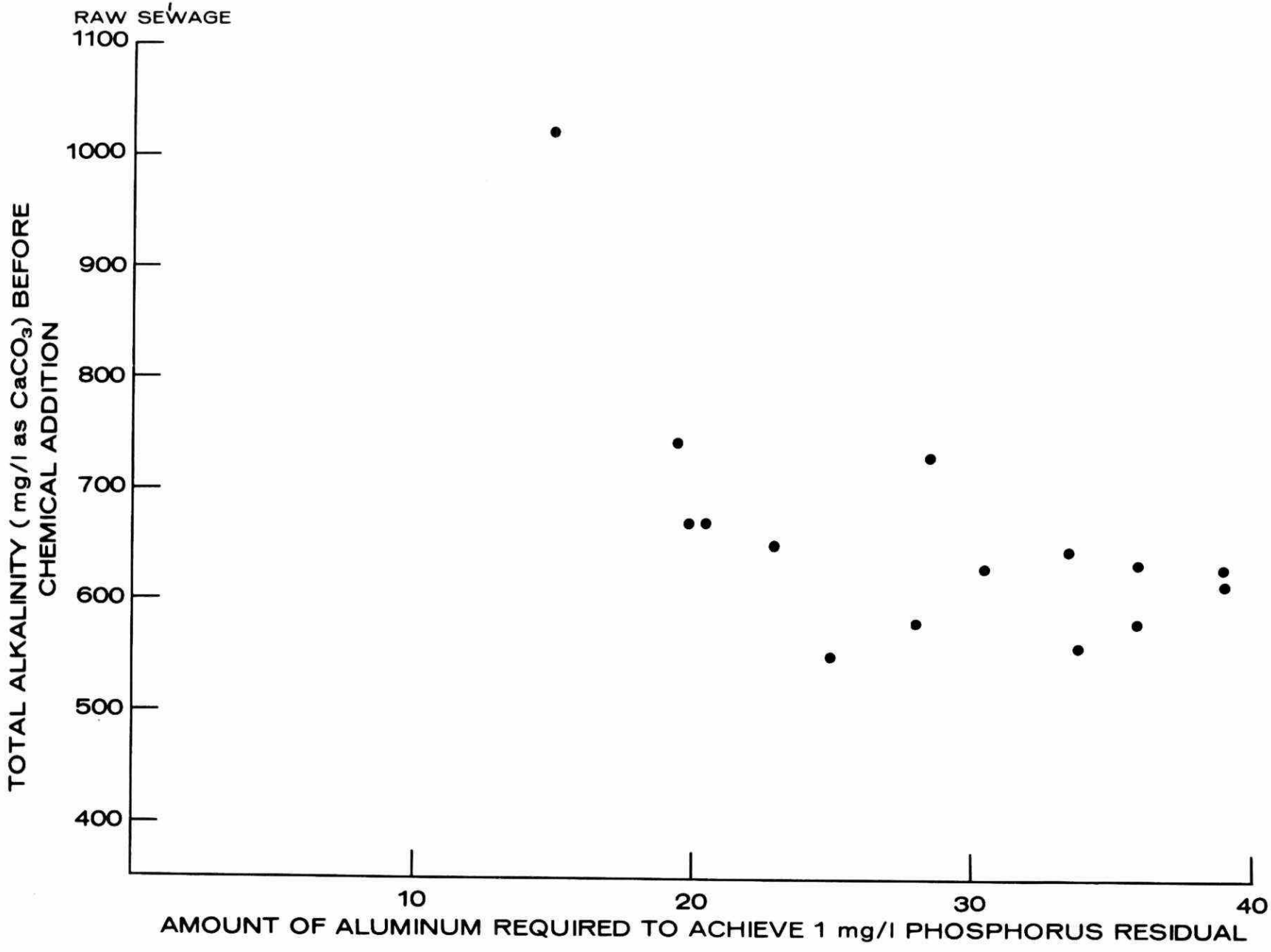


FIGURE 16 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE A 1 ppm PHOSPHORUS RESIDUAL VS HARDNESS BEFORE CHEMICAL ADDITION

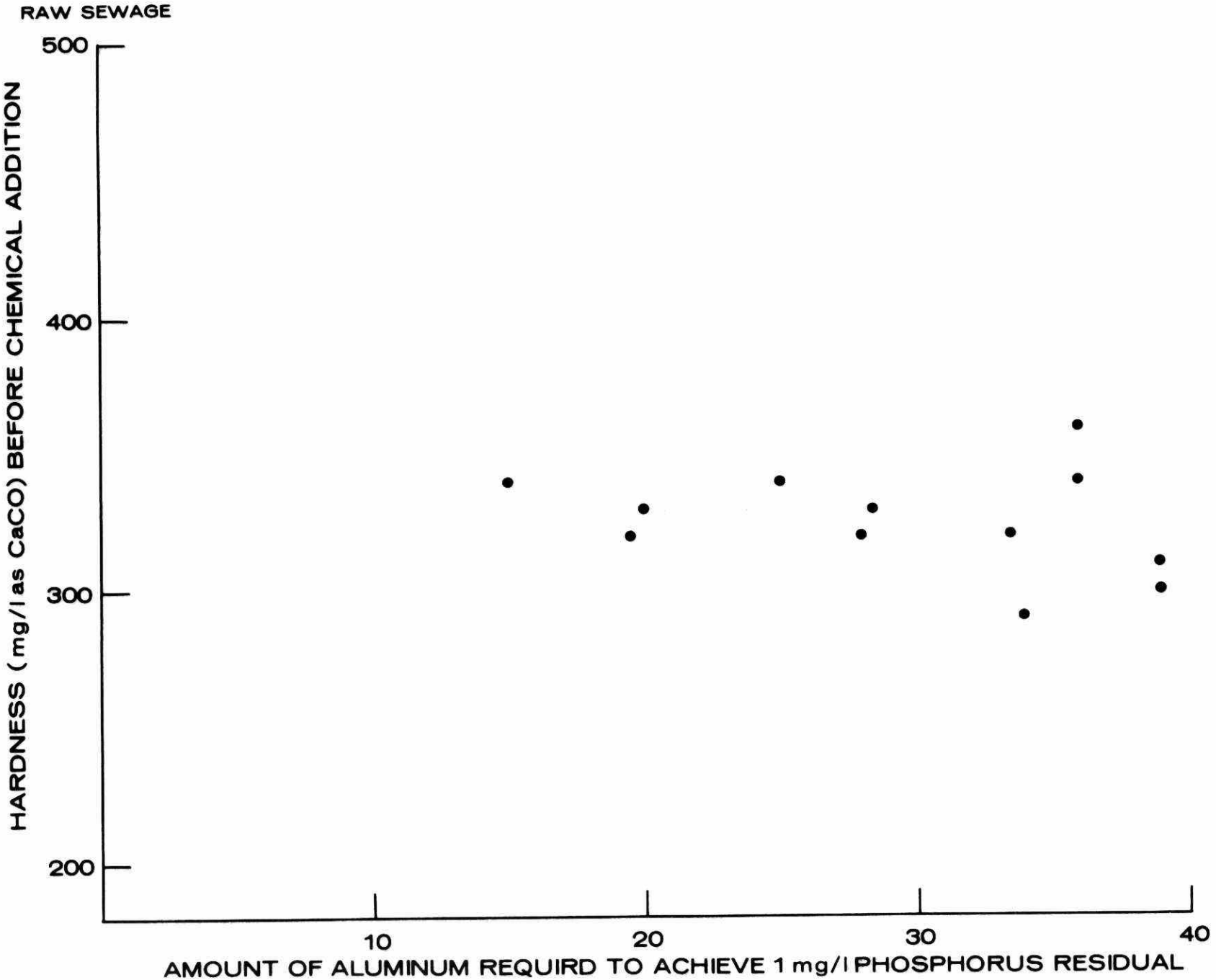


FIGURE 17. AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL VS TURBIDITY BEFORE CHEMICAL ADDITION

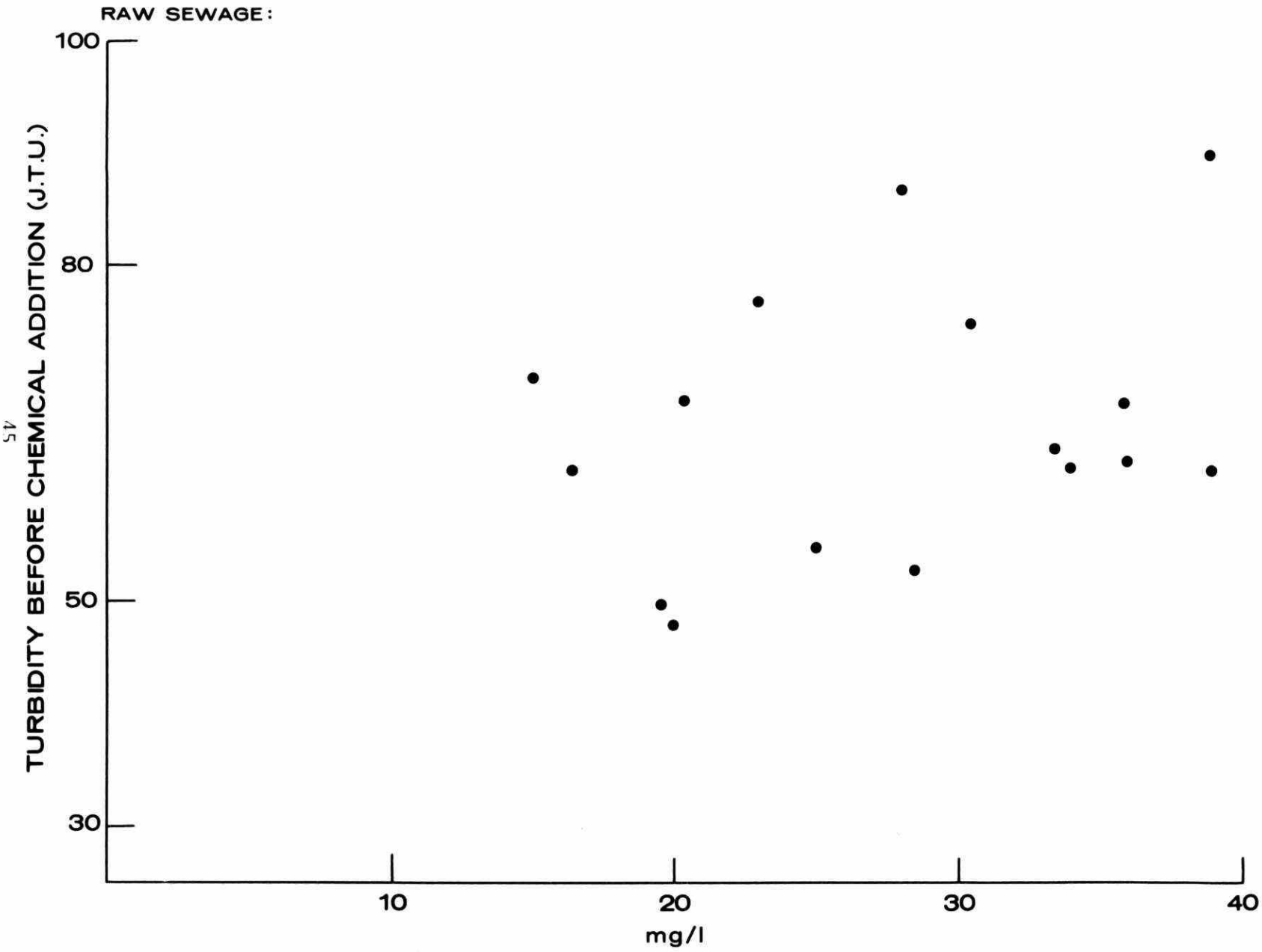


FIGURE 18. AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL VS CONDUCTIVITY BEFORE CHEMICAL ADDITION

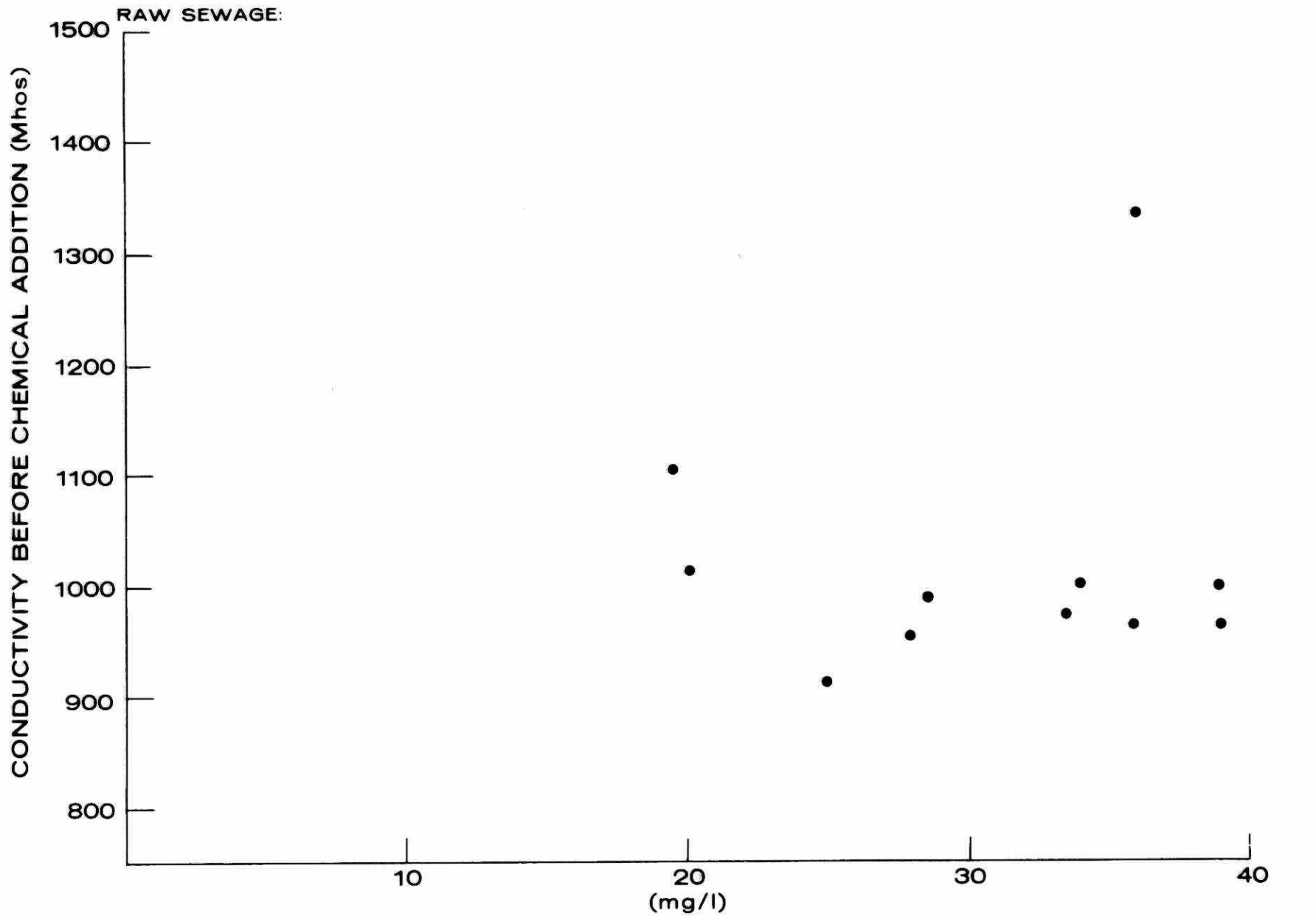


FIGURE 19. AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE A 1 mg/l PHOSPHORUS RESIDUAL VS TOTAL PHOSPHORUS CONCENTRATION BEFORE CHEMICAL ADDITION

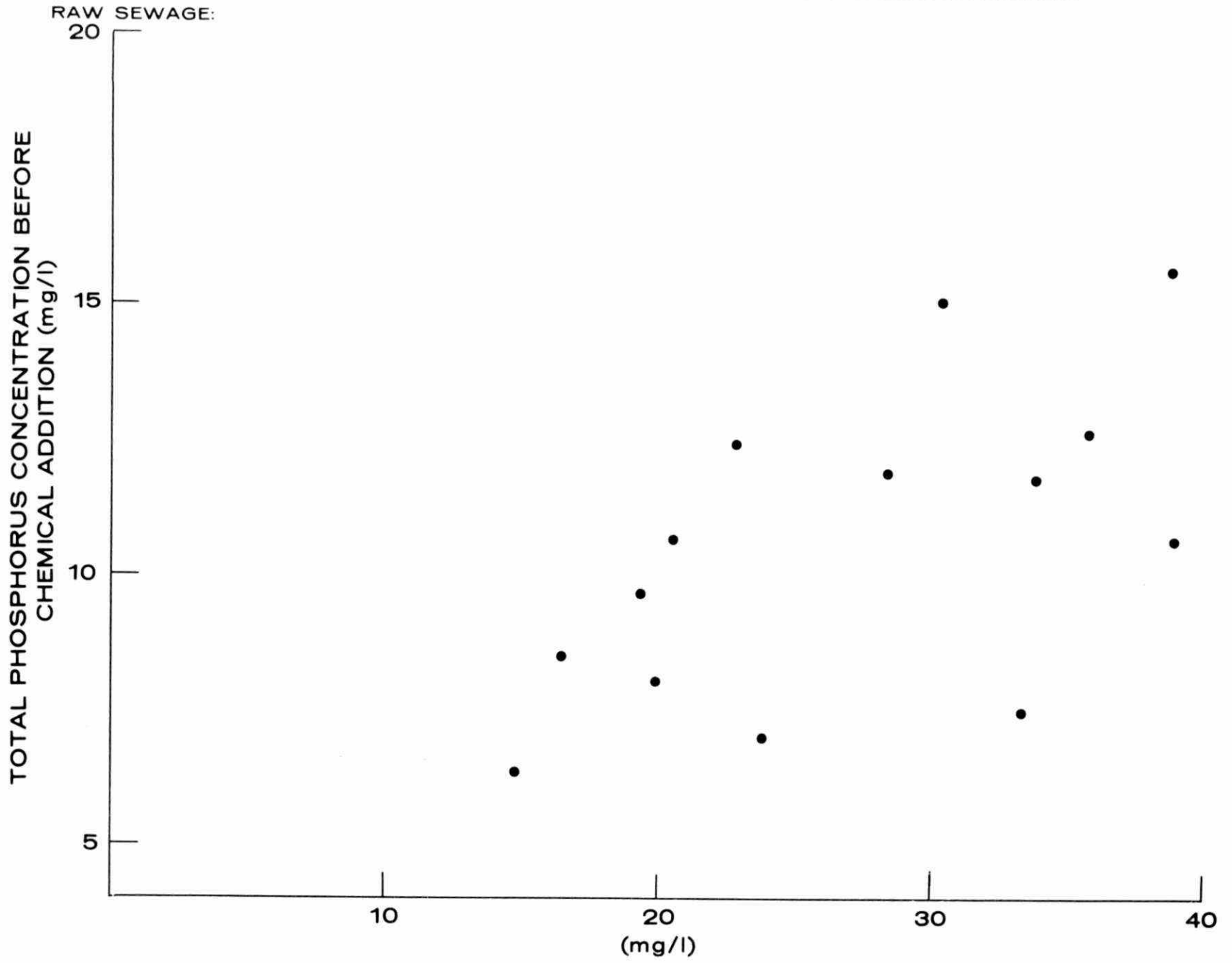


FIGURE 20. AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL VS pH BEFORE CHEMICAL ADDITION

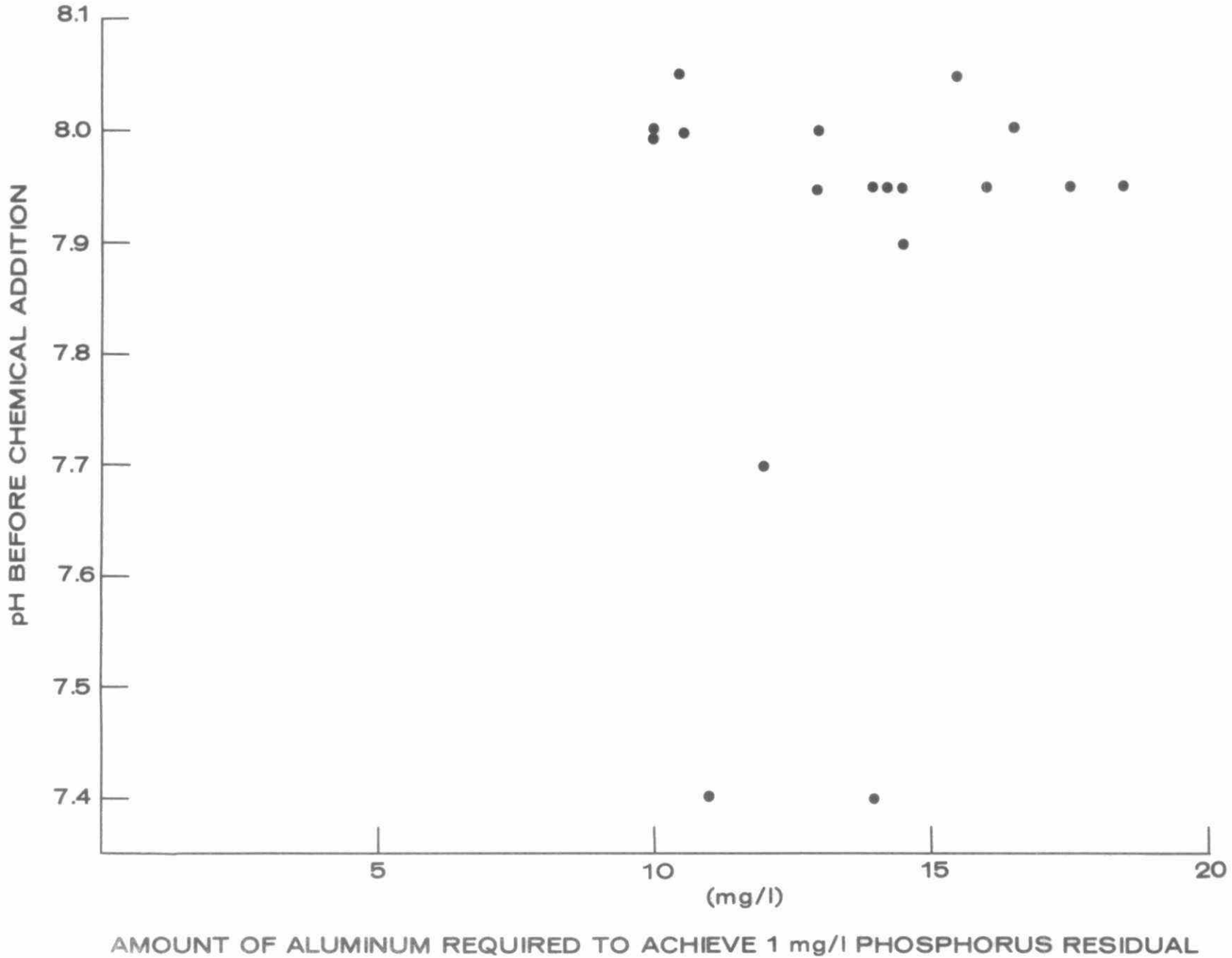


FIGURE 21 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 ppm PHOSPHORUS RESIDUAL VS TOTAL ALKALINITY BEFORE CHEMICAL ADDITION

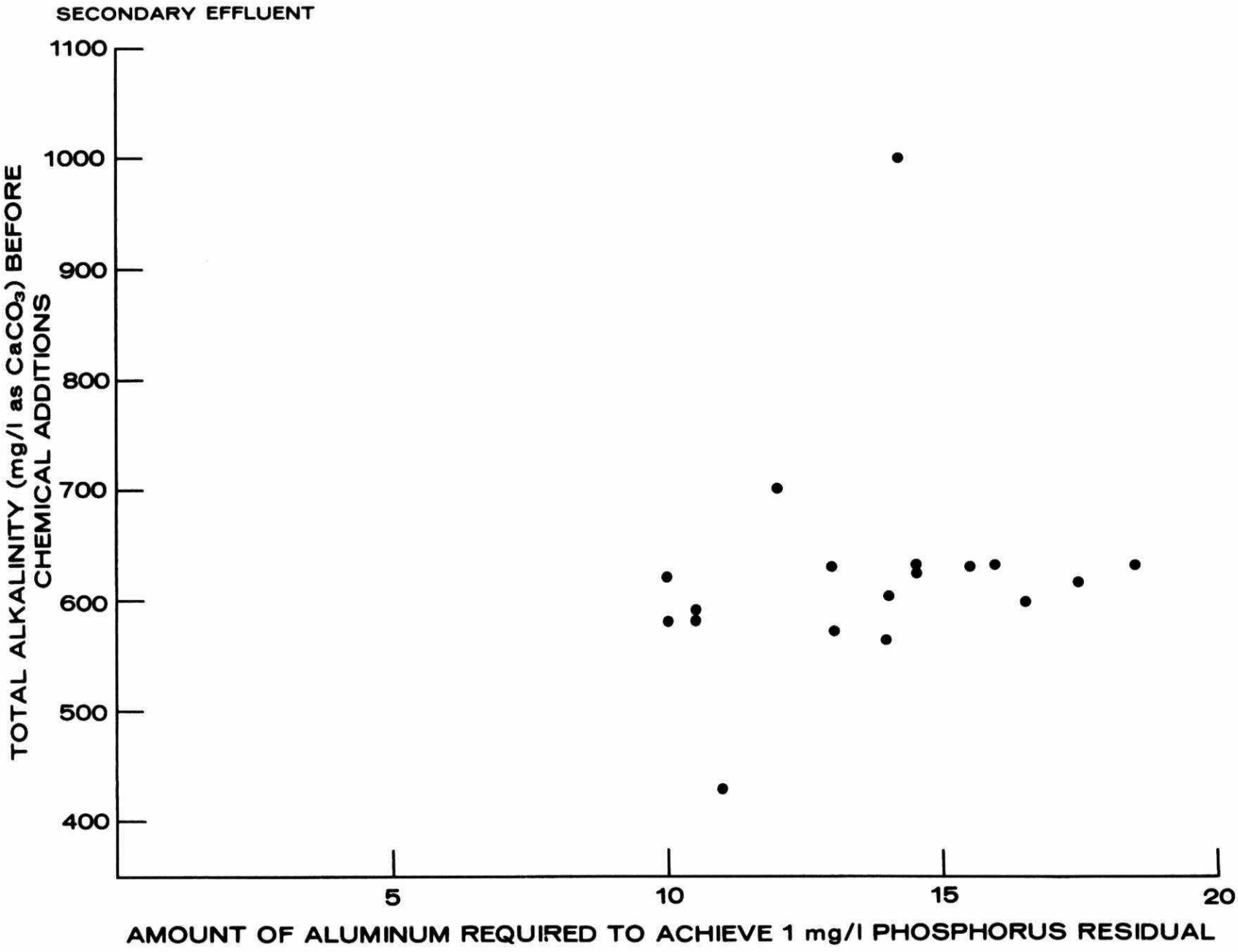


FIGURE 22 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 ppm PHOSPHORUS RESIDUAL VS HARDNESS BEFORE CHEMICAL ADDITION

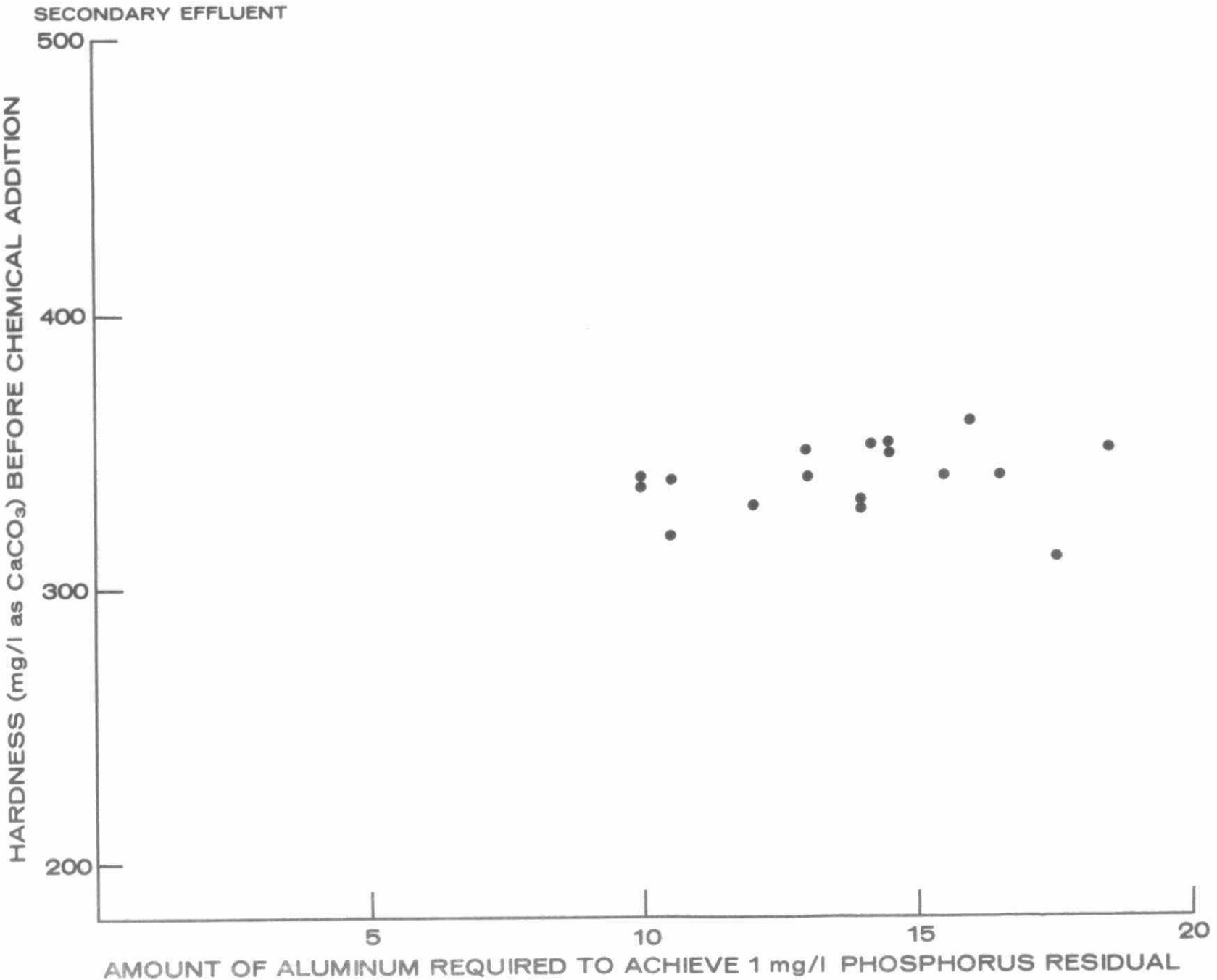


FIGURE 23 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1mg/l PHOSPHORUS RESIDUAL VS TURBIDITY BEFORE CHEMICAL ADDITION

SECONDARY EFFLUENT:

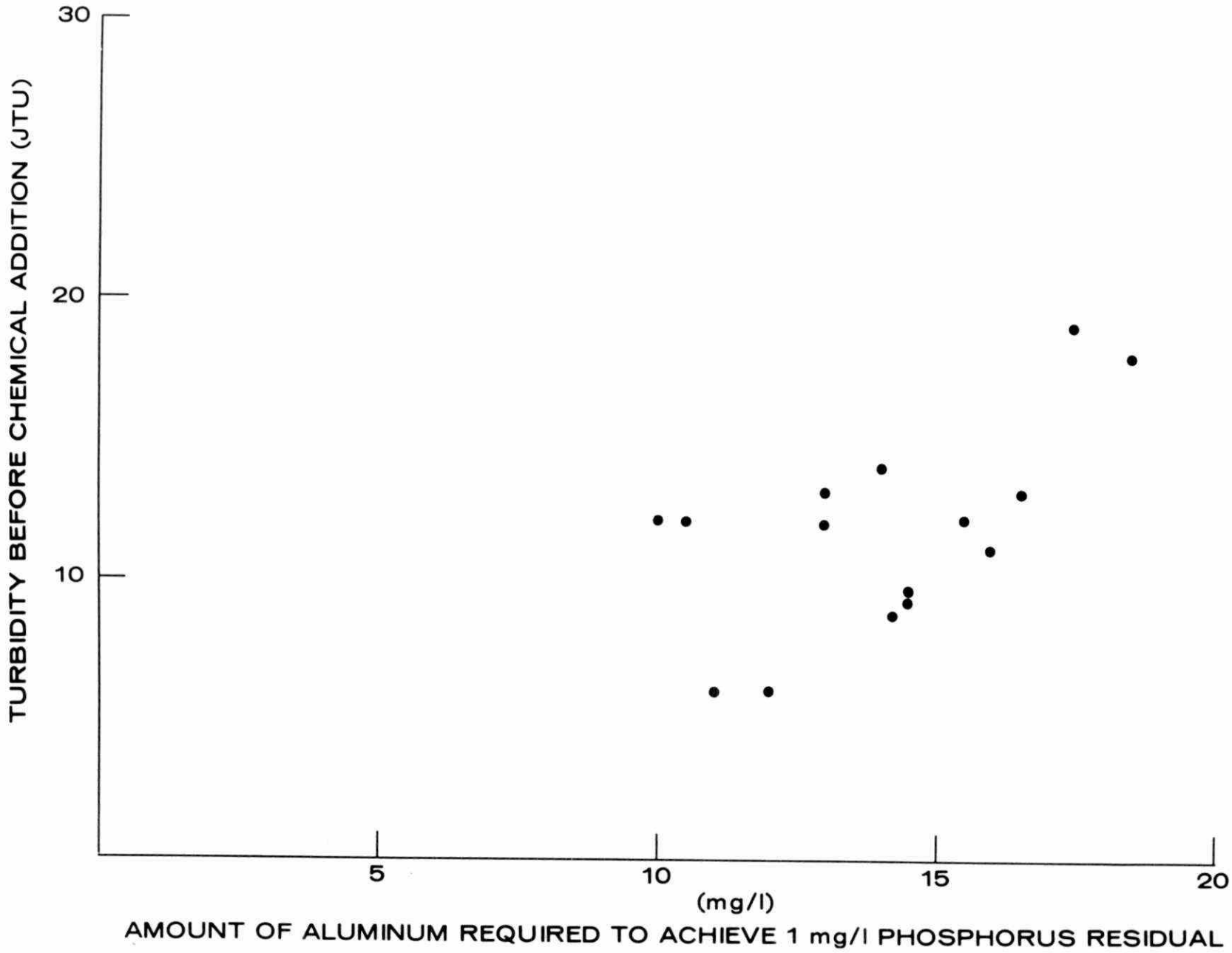


FIGURE 24 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL VS PHOSPHORUS CONCENTRATION BEFORE CHEMICAL ADDITION

SECONDERY EFFLUENT:

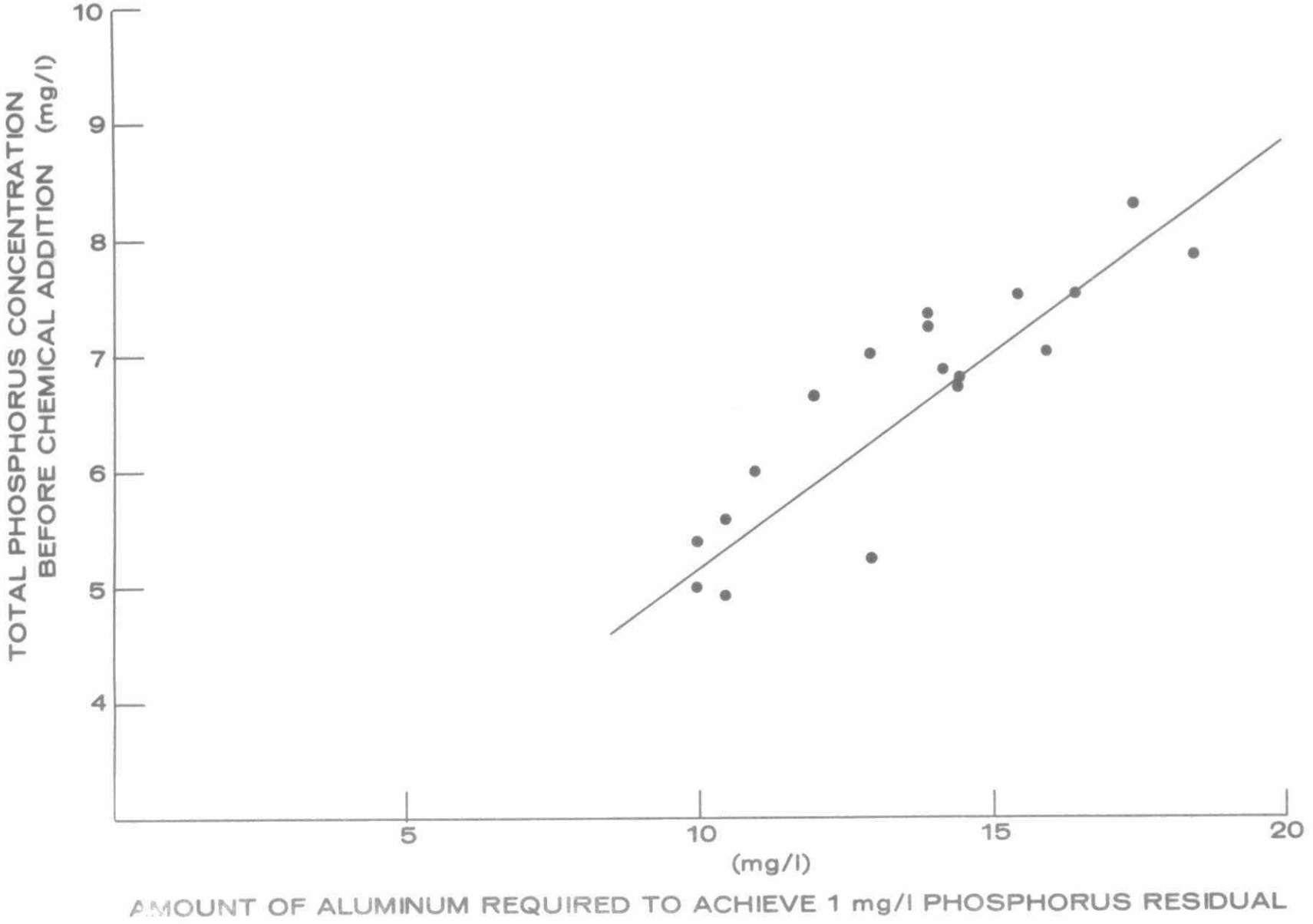


FIGURE 25 AMOUNT OF ALUMINUM REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL VS CONDUCTIVITY BEFORE CHEMICAL ADDITION

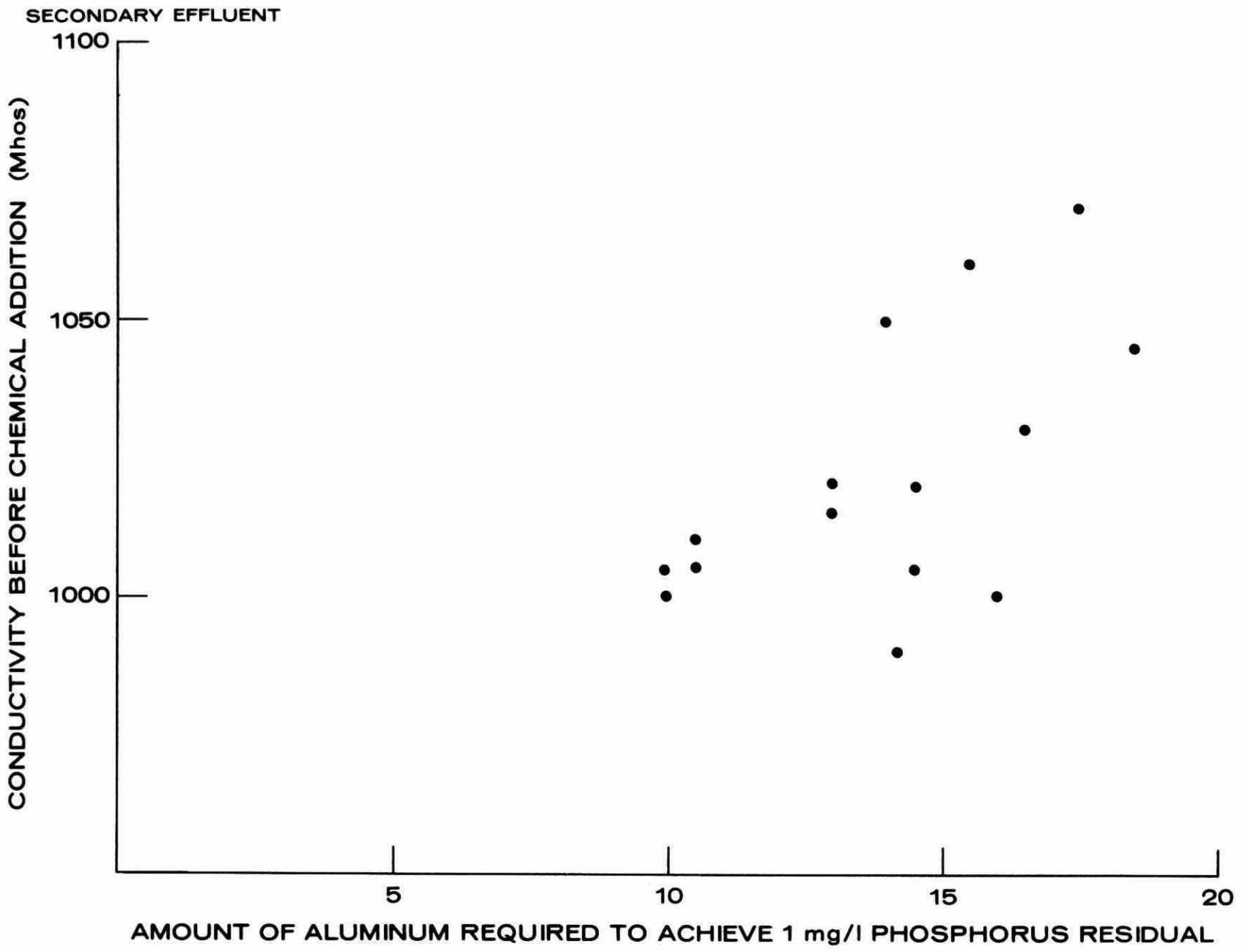


FIGURE 26A ADDITION OF Al TO RAW SEWAGE

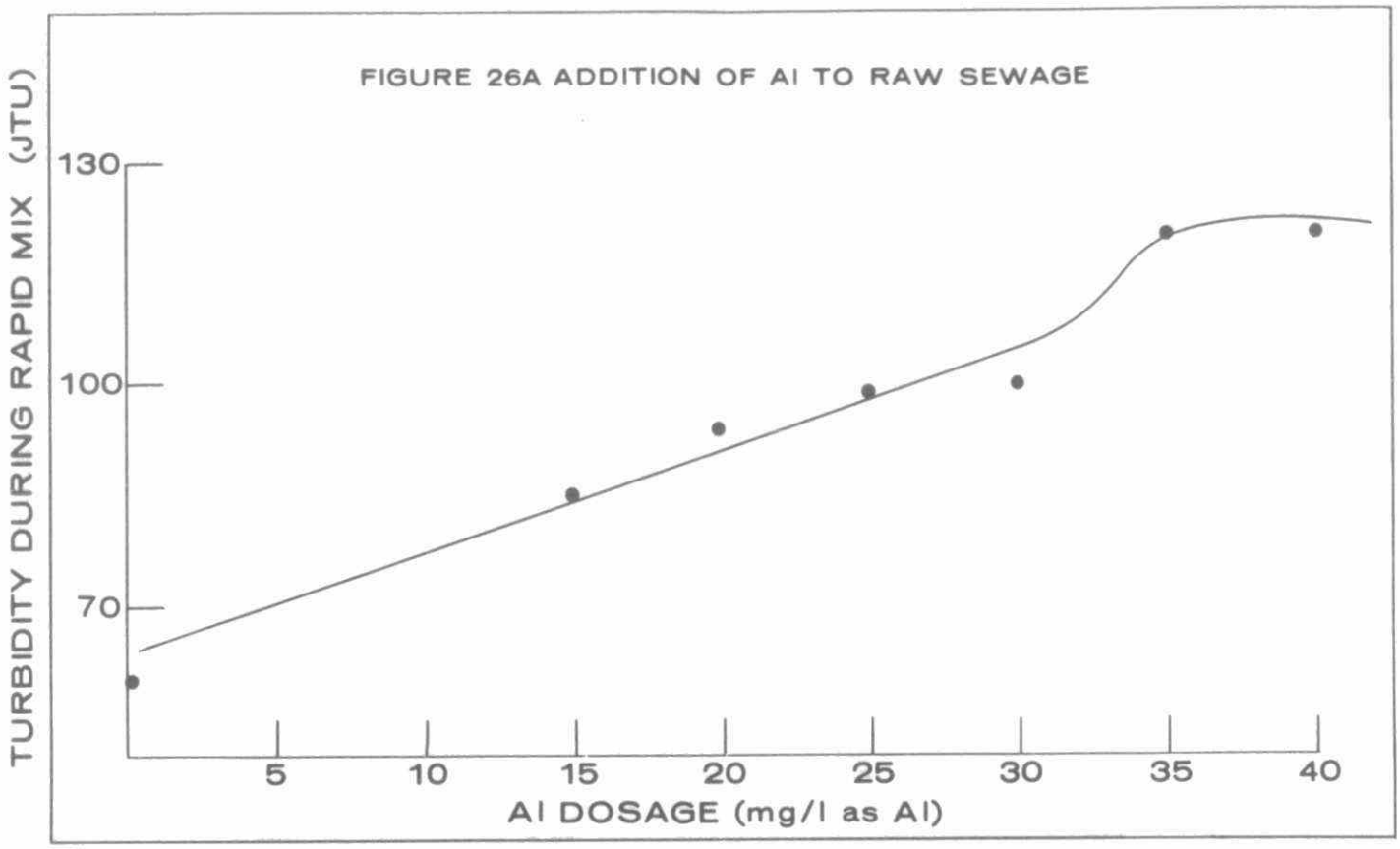


FIGURE 26B ADDITION OF Al TO SECONDARY EFFLUENT

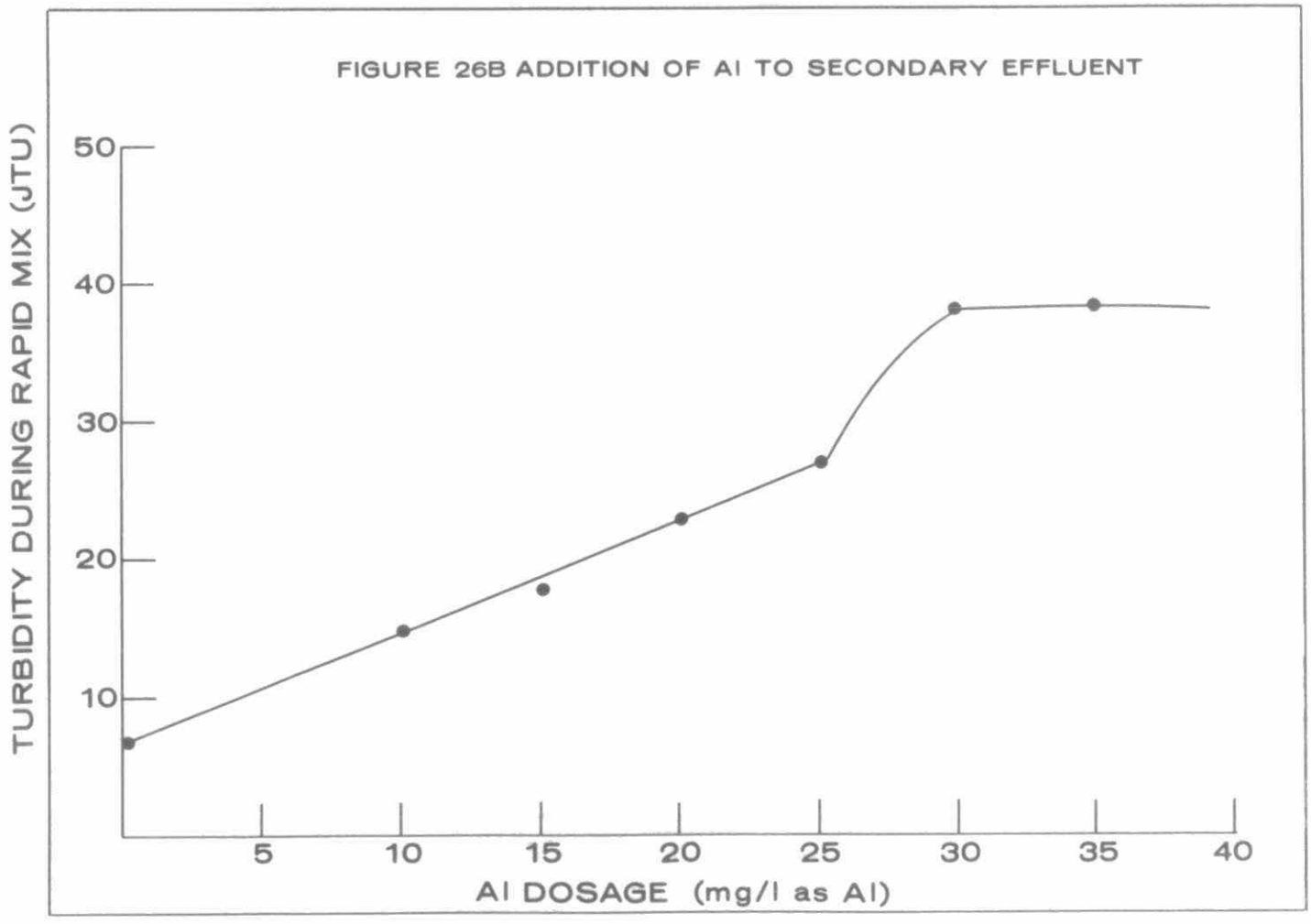


FIGURE 27 RESIDUAL PHOSPHORUS VS TURBIDITY OF RAW SEWAGE AFTER CHEMICAL ADDITION AND ½ HOUR OF QUIESCENT SETTLING

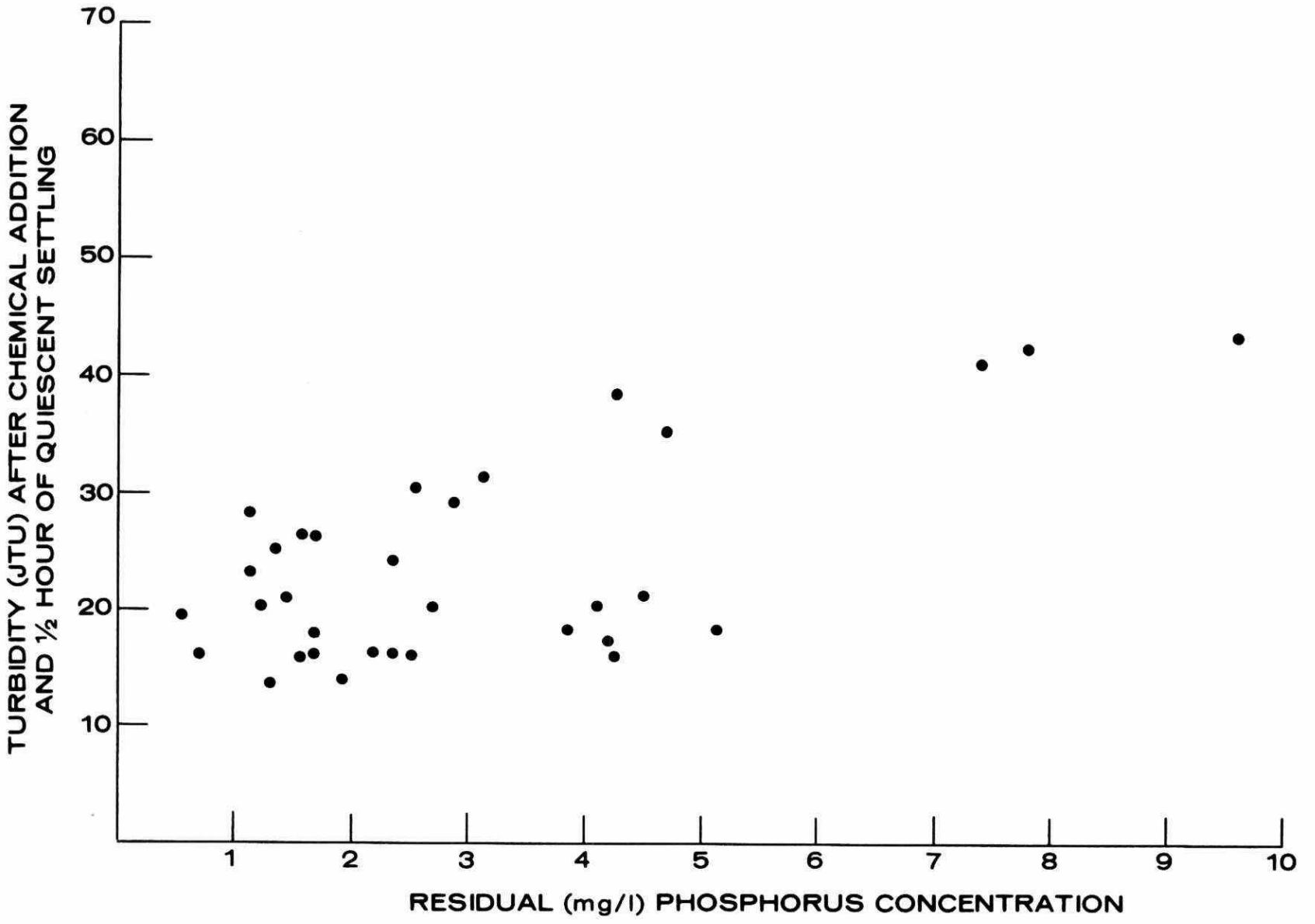


FIGURE 28A ADDITION OF Al TO SECONDARY EFFLUENT

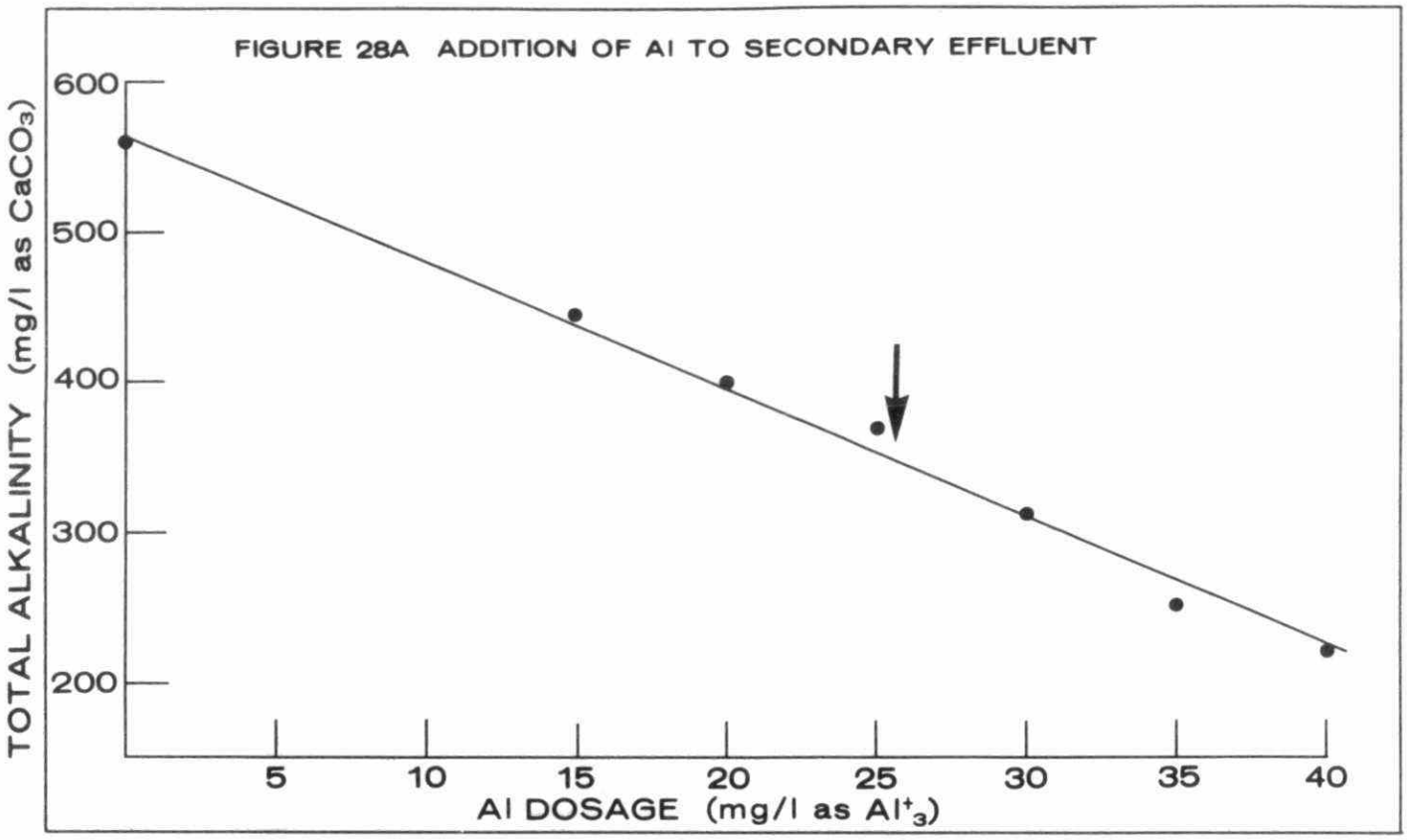


FIGURE 28B ADDITION OF Al TO RAW SEWAGE

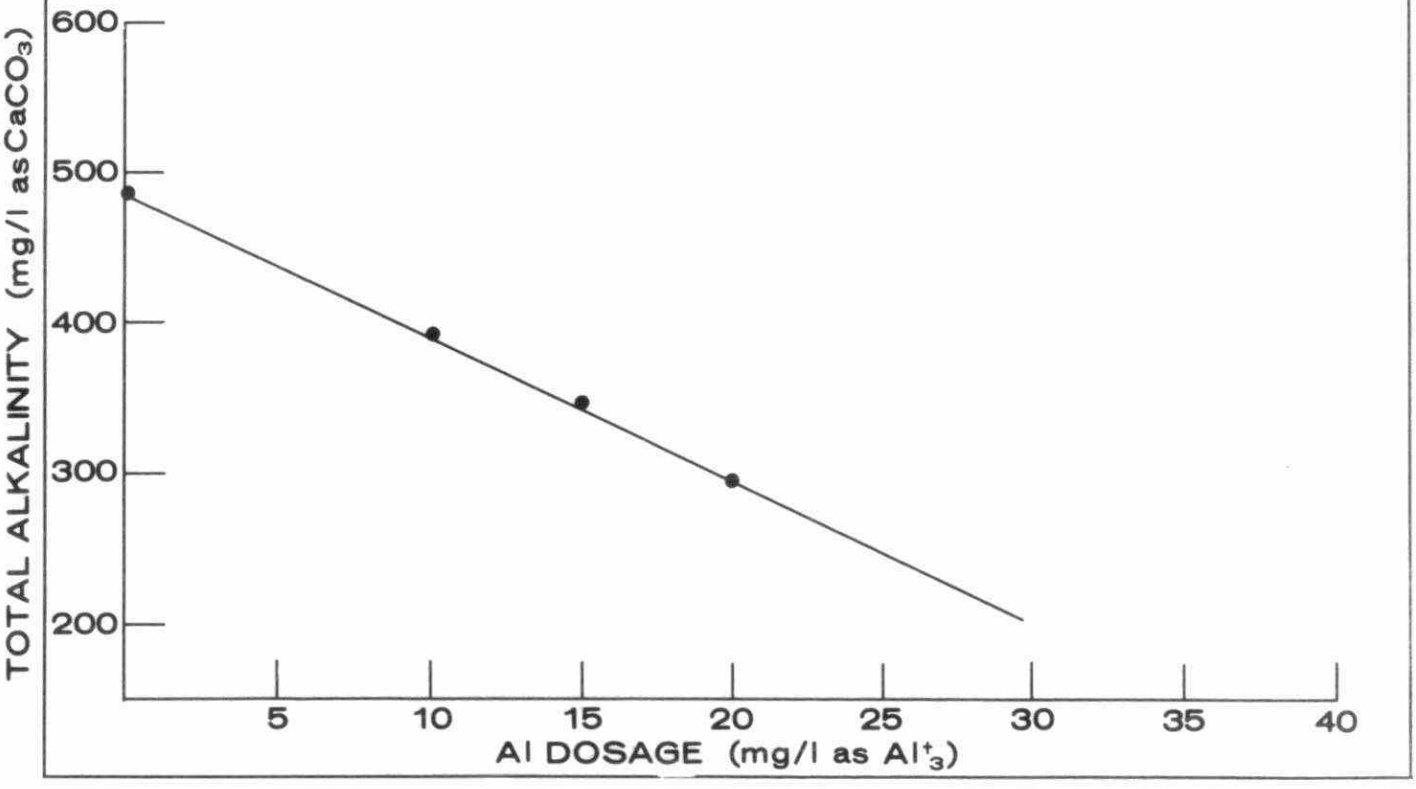


FIGURE 29A ADDITION OF A1 TO RAW SEWAGE

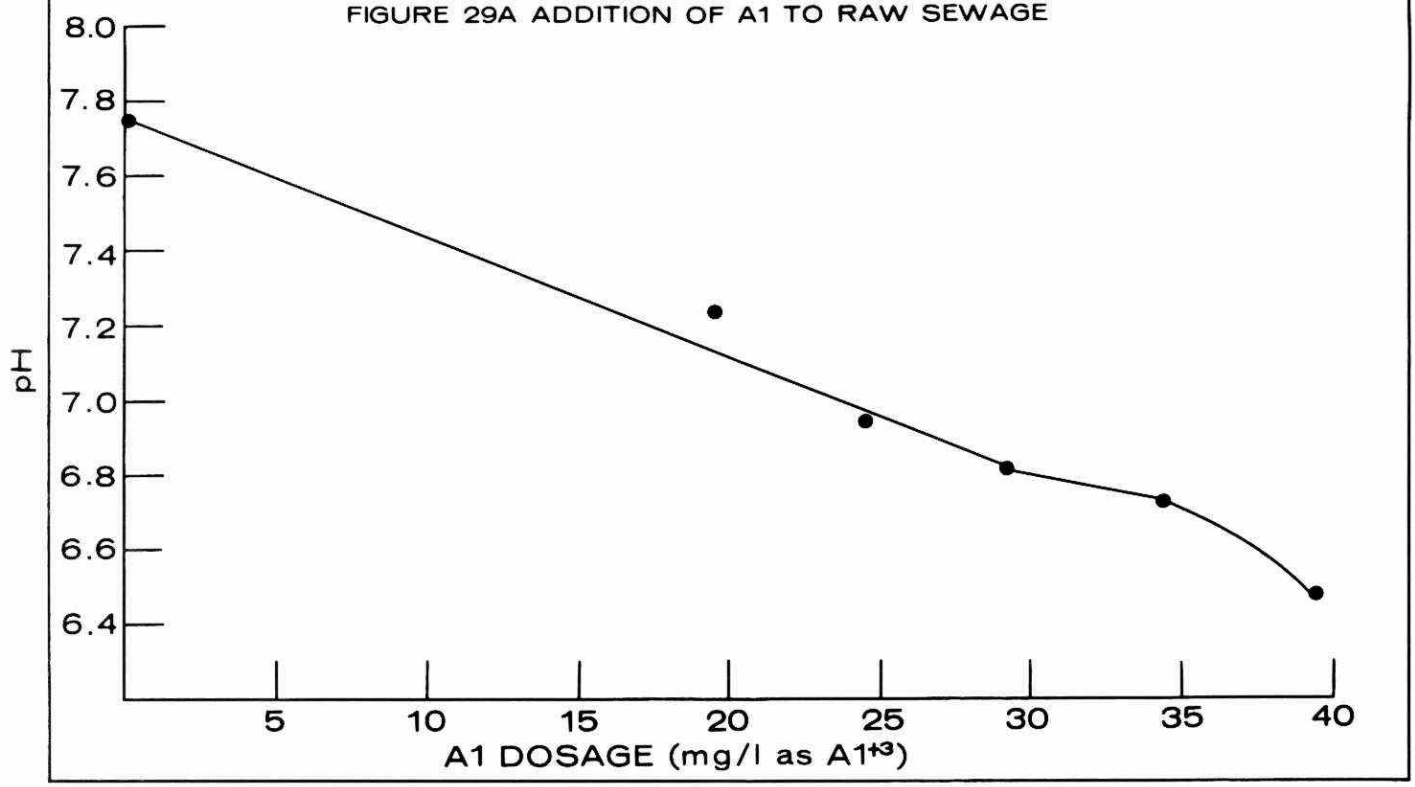


FIGURE 29B ADDITION OF A1 TO SECONDARY EFFLUENT

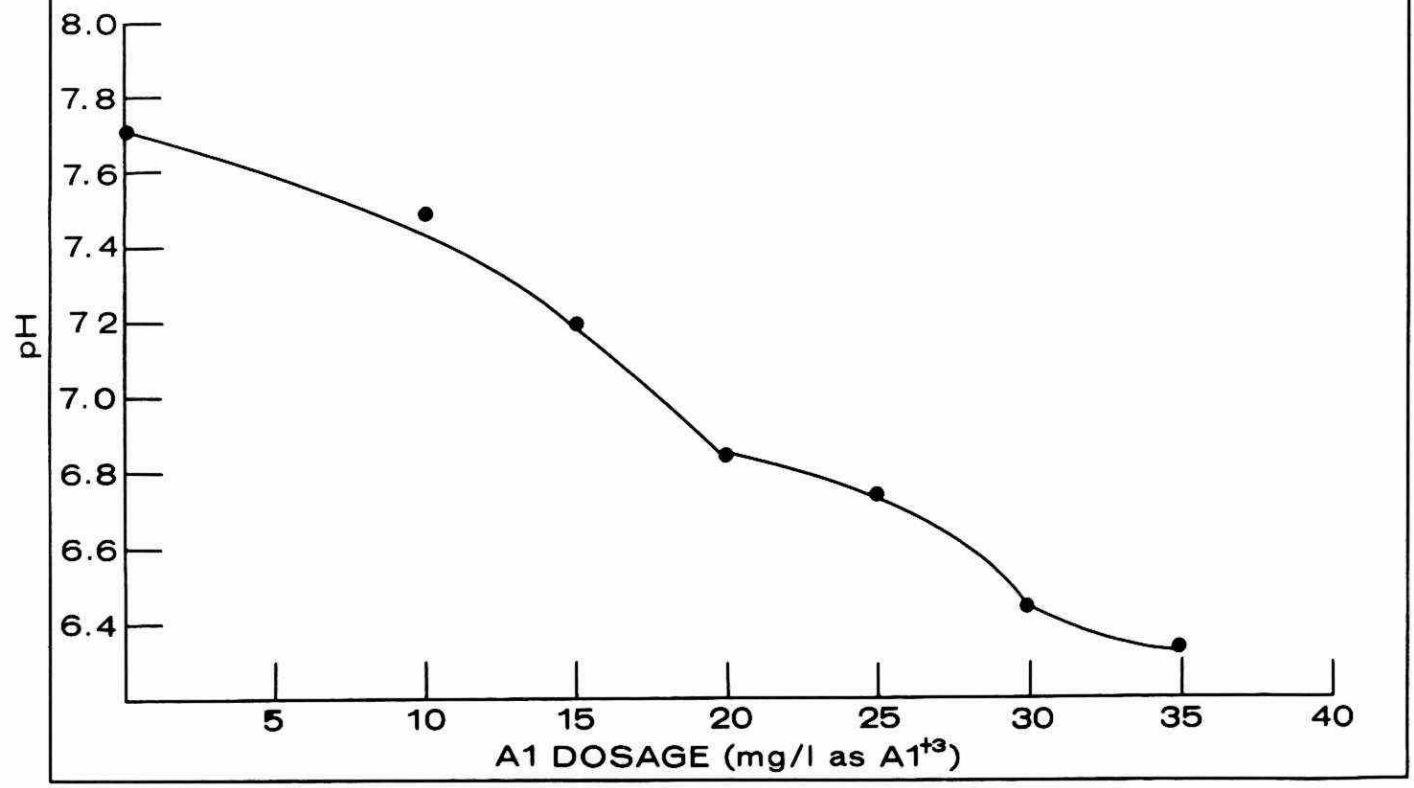


FIGURE 30 CHEMICAL DOSAGE CONTROL SCHEMES

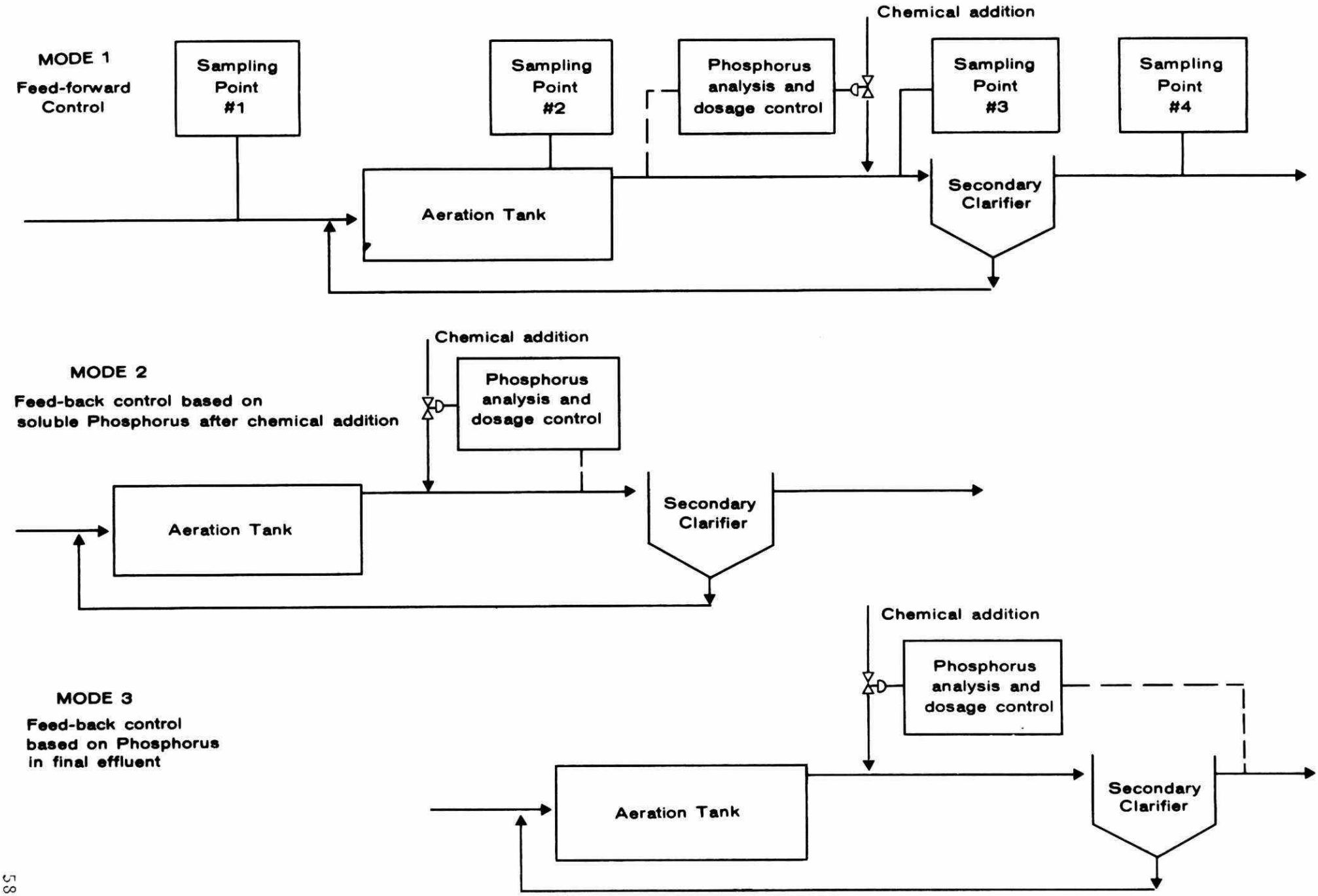


FIGURE 31 PHOSPHORUS REMOVAL STUDIES,FEBRUARY 6,7 1973
ALUM DOSAGE AND PHOSPHORUS CONCENTRATIONS

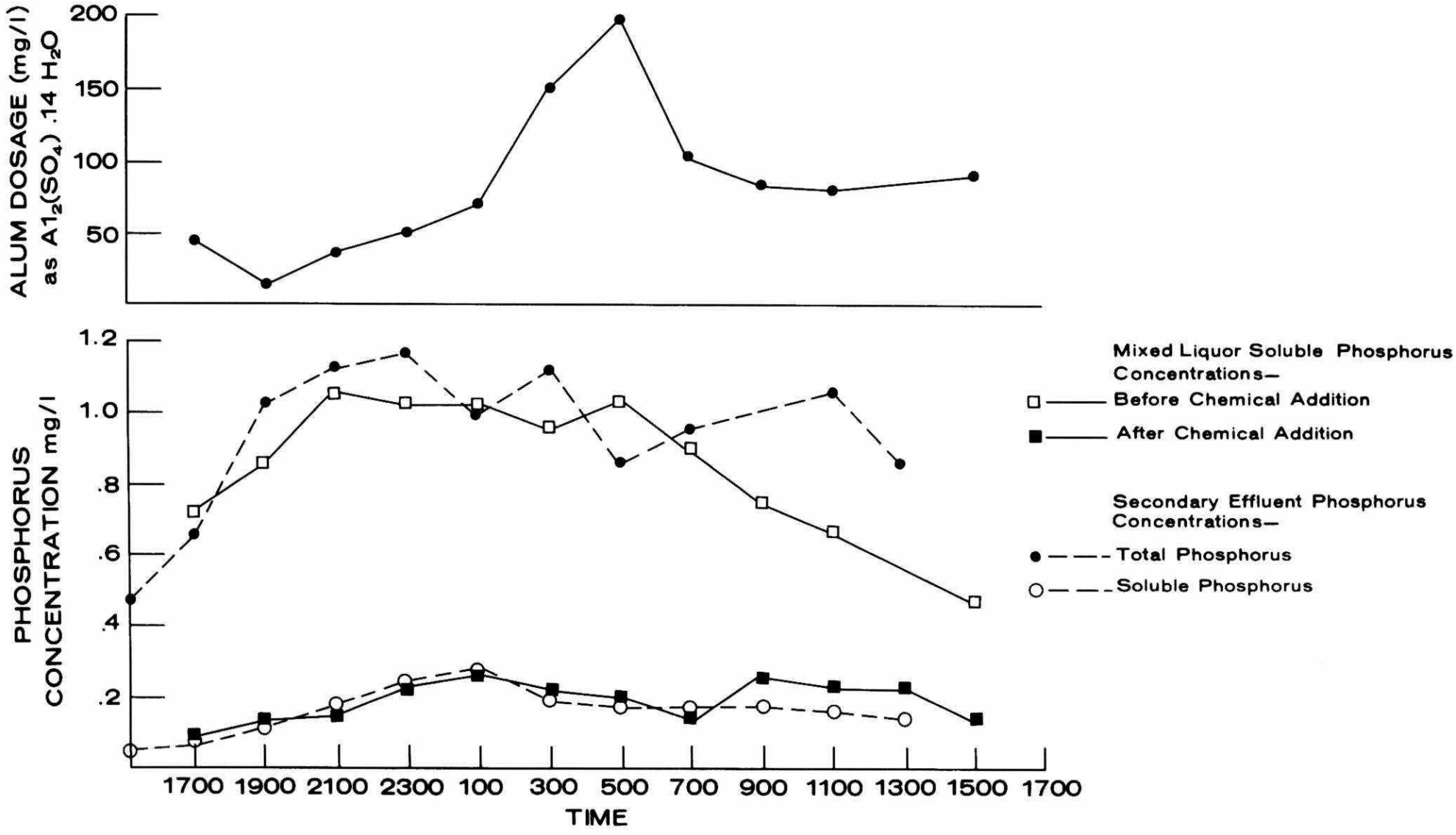


FIGURE 32 PHOSPHORUS REMOVAL STUDIES, FEBRUARY 21,22,26,27,1973
ALUM DOSAGE AND PHOSPHORUS CONCENTRATIONS

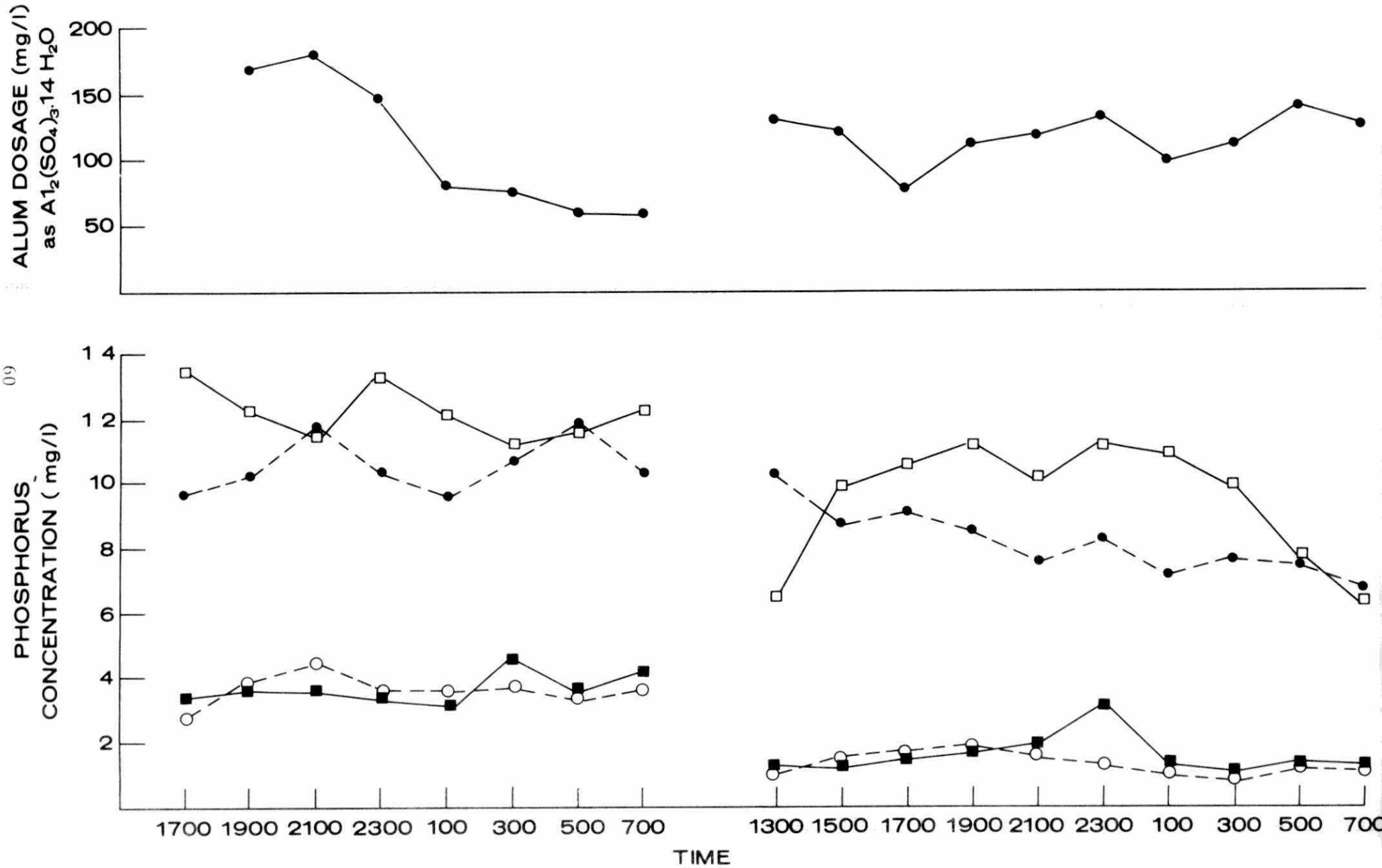


FIGURE 33 PHOSPHORUS REMOVAL STUDIES,MARCH 1, 1973 ALUM DOSAGE AND PHOSPHORUS CONCENTRATIONS

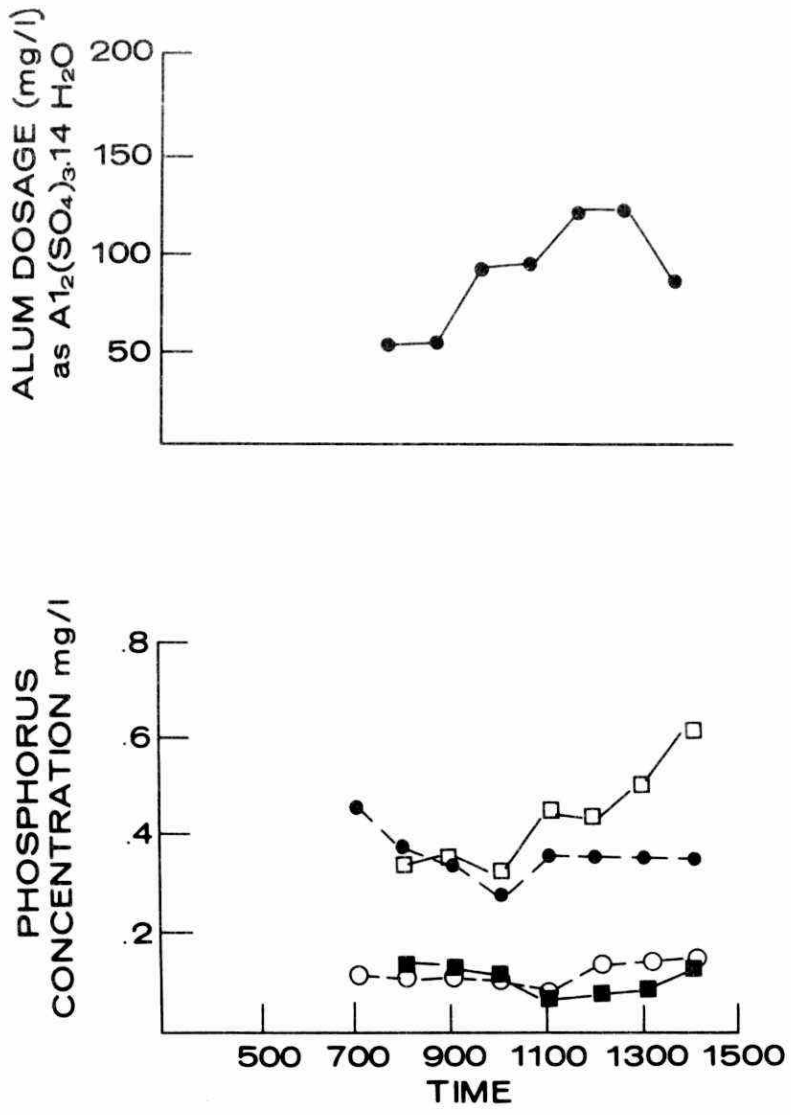


FIGURE 34 PHOSPHORUS REMOVAL STUDIES, MARCH 12, 13, 14, 1973
ALUM DOSAGE AND PHOSPHORUS CONCENTRATIONS

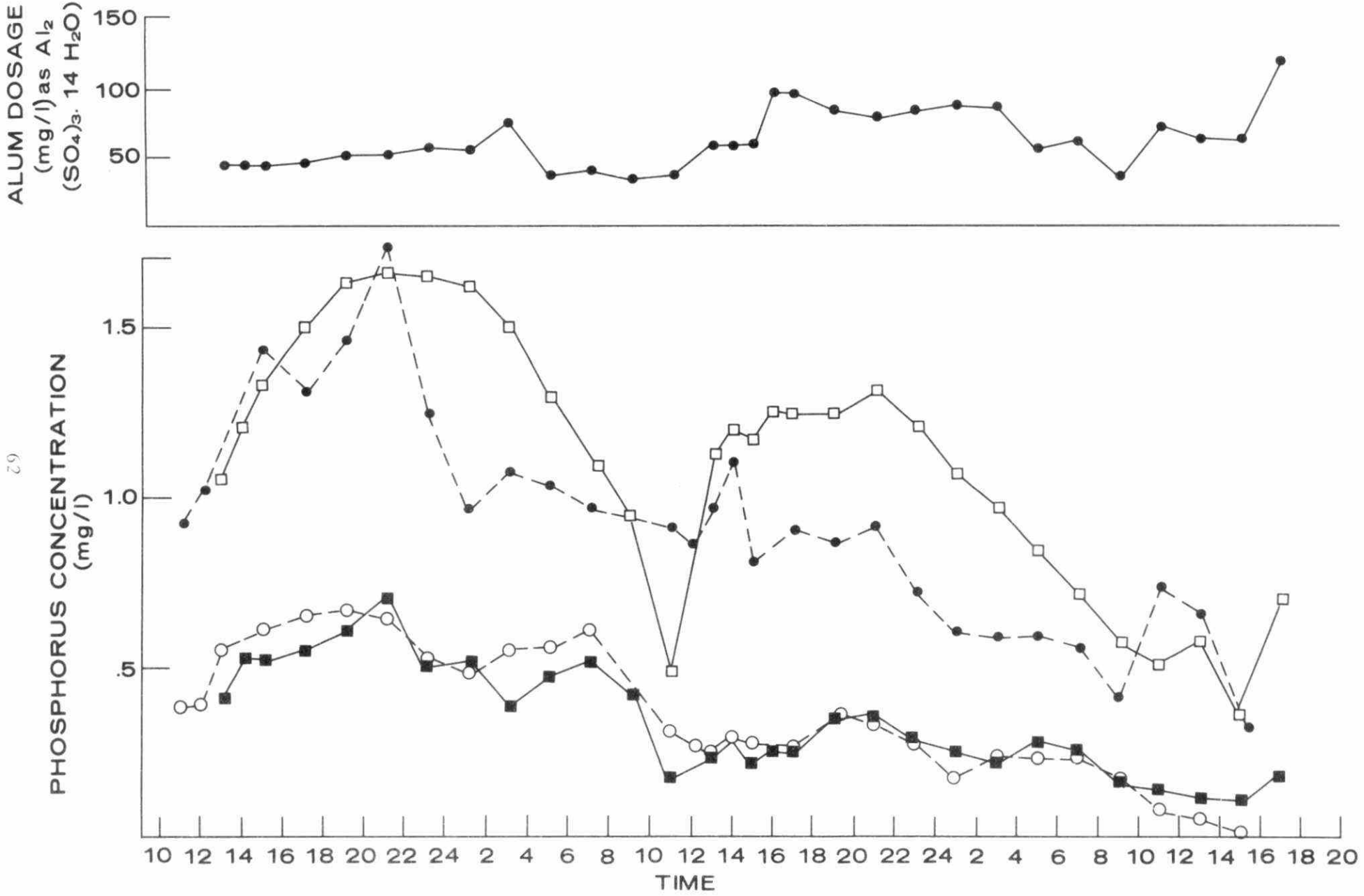


FIGURE 35 KITCHENER WATER POLLUTION CONTROL PLANT
PHOSPHORUS PROFILE IN RAW SEWAGE

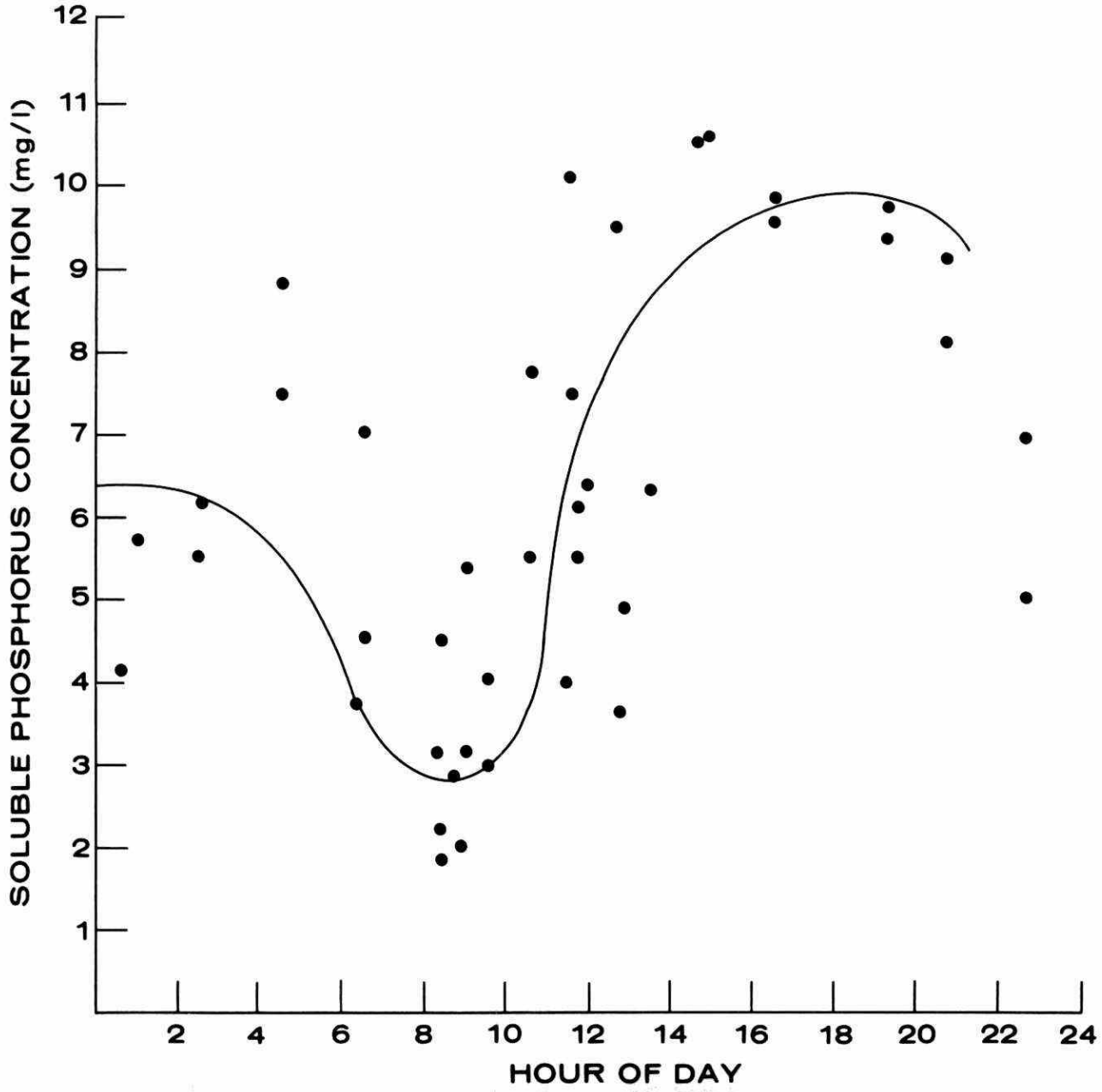


FIGURE 36 CORRELATION BETWEEN TOTAL PHOSPHORUS CONCENTRATION IN SECONDARY EFFLUENT AND SOLUBLE PHOSPHORUS CONCENTRATION IN MIXED LIQUOR FOLLOWING CHEMICAL ADDITION

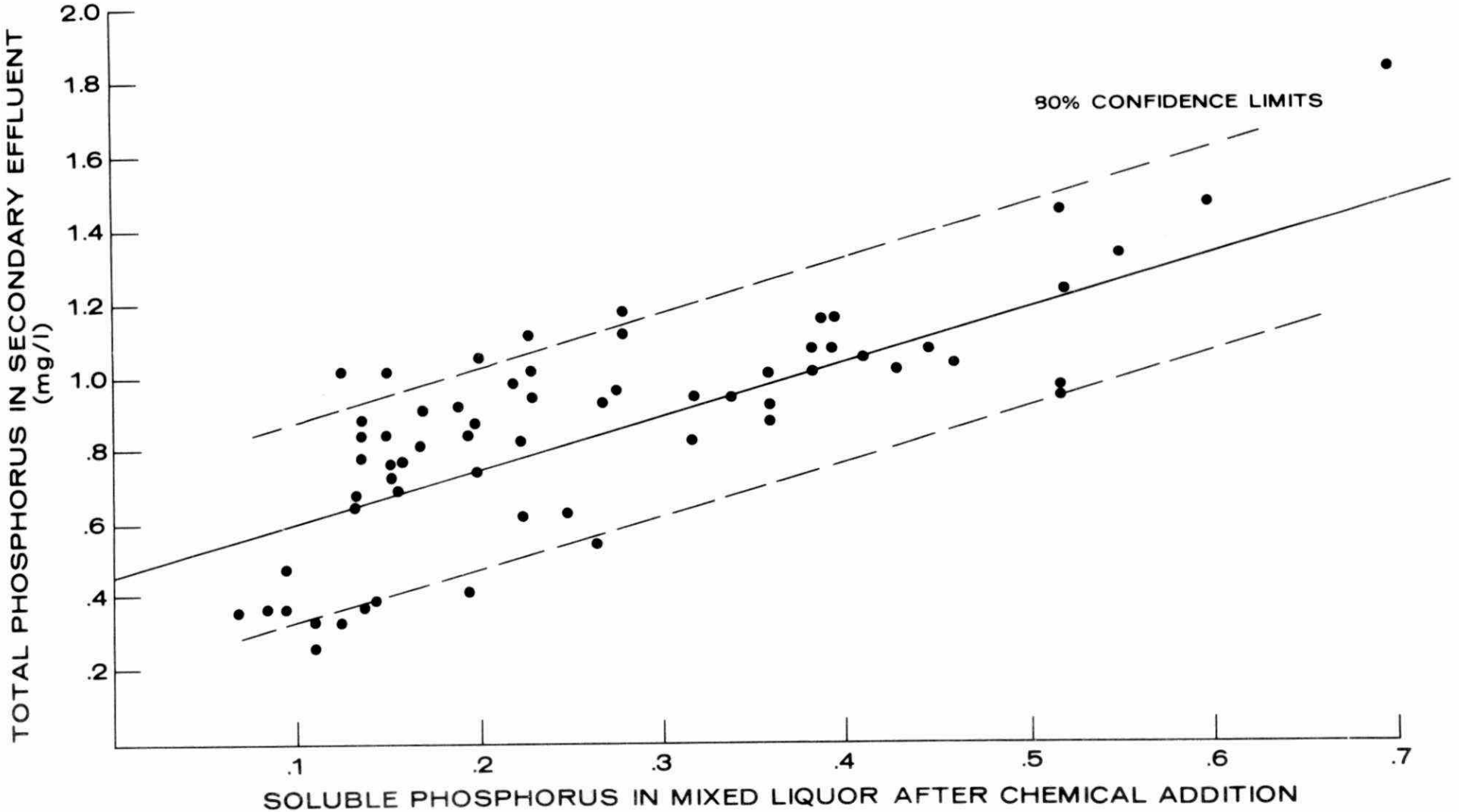


FIGURE 37 PERCENTAGE OF FINAL EFFLUENT WITH PHOSPHORUS CONCENTRATION LESS THAN 1mg/l VS SOLUBLE PHOSPHORUS CONCENTRATION IN MIXED LIQUOR AFTER ALUM ADDITION

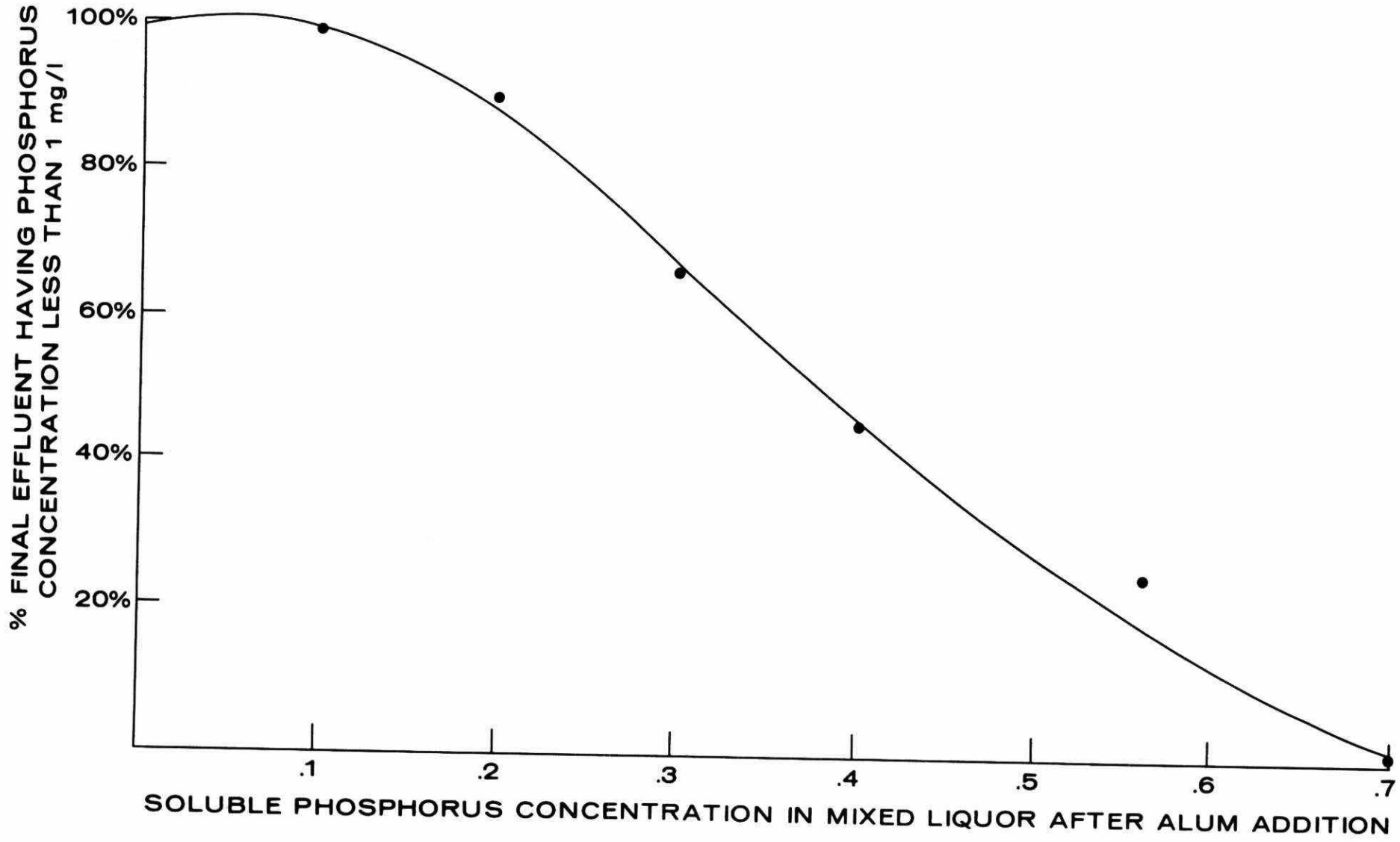


FIGURE 38 REMOVAL OF SOLUBLE PHOSPHORUS IN MIXED LIQUOR AS A FUNCTION OF ALUM DOSAGE USED

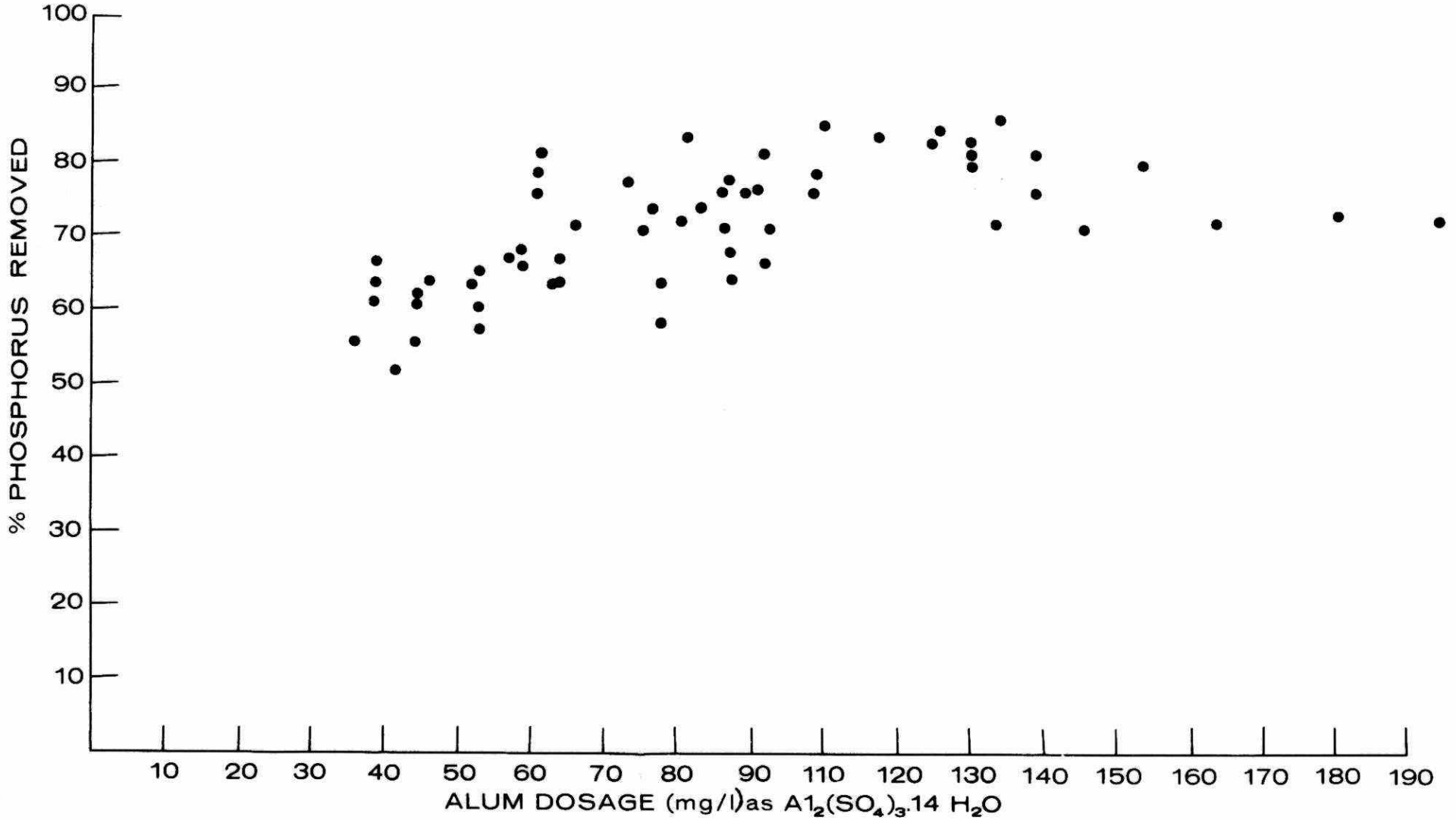


FIGURE 39 REMOVAL OF SOLUBLE PHOSPHORUS IN MIXED LIQUOR AS A FUNCTION OF SOLUBLE PHOSPHORUS CONCENTRATION BEFORE CHEMICAL ADDITION

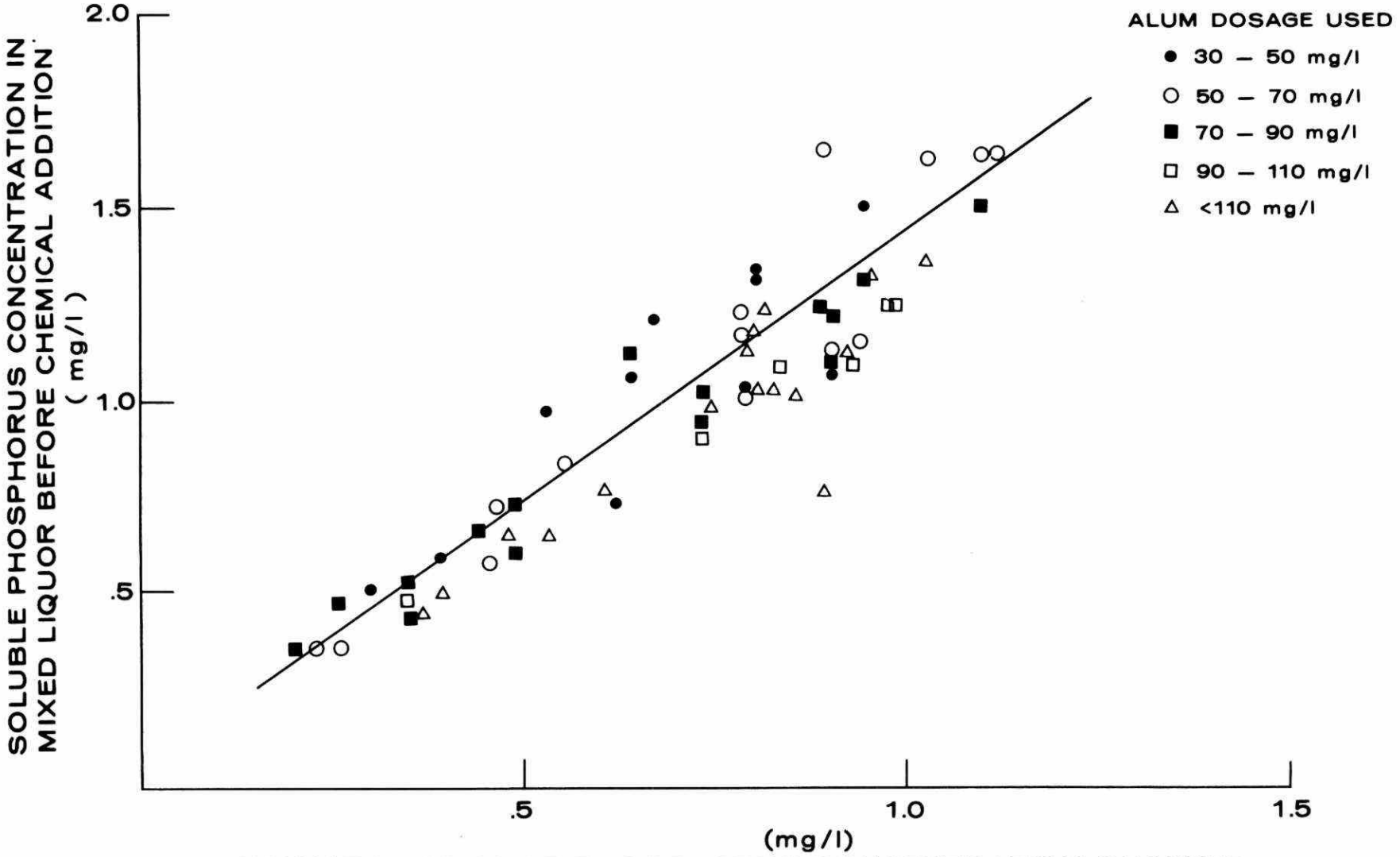


FIGURE 40 TOTAL PHOSPHORUS CONCENTRATION IN FINAL EFFLUENT VERSUS ALUM DOSAGE (Based on two hour sampling periods)

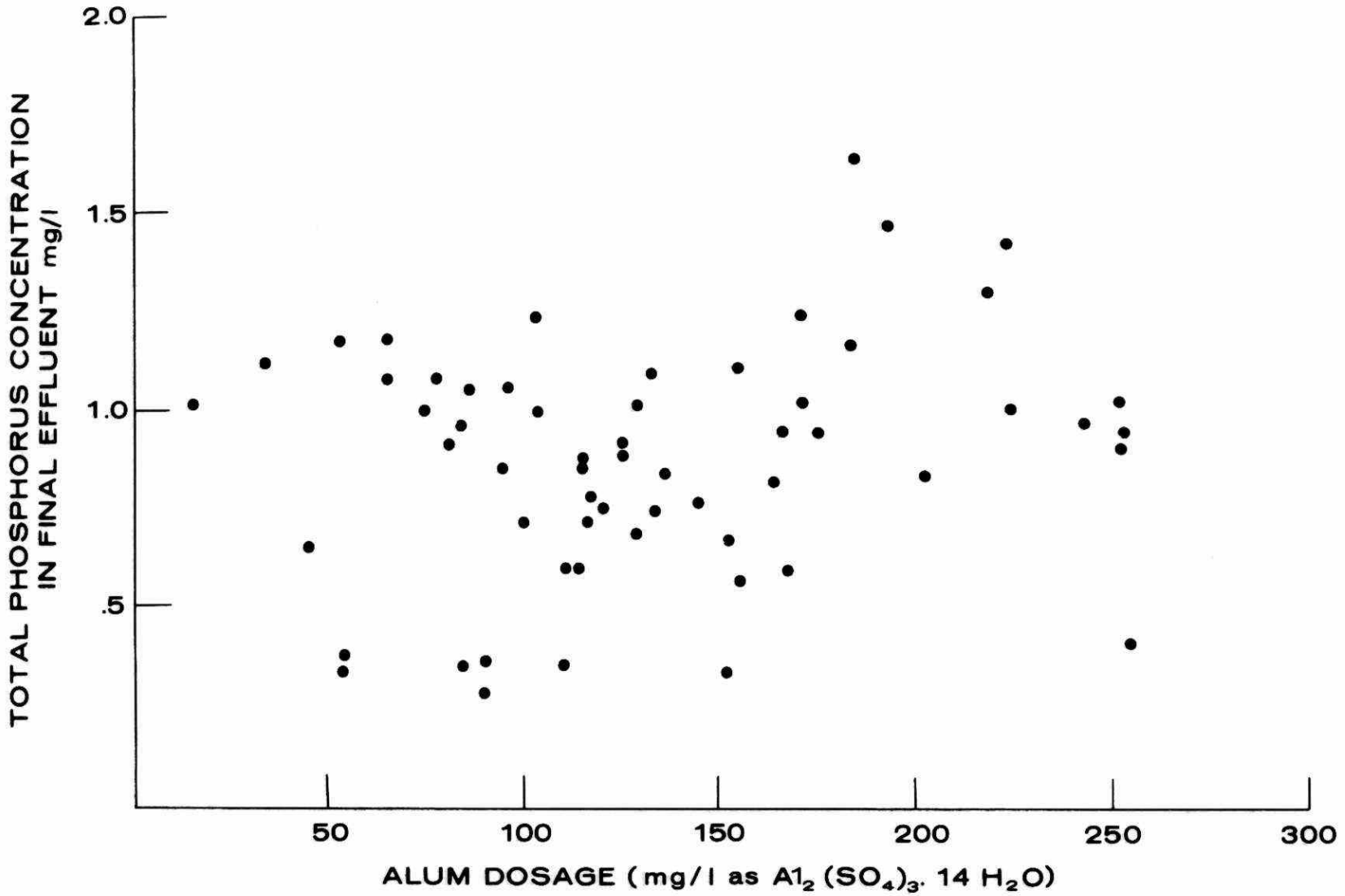


FIGURE 41 PHOSPHORUS REMOVAL STUDY ALUM DOSAGE AND PHOSPHORUS CONCENTRATION IN FINAL EFFLUENT

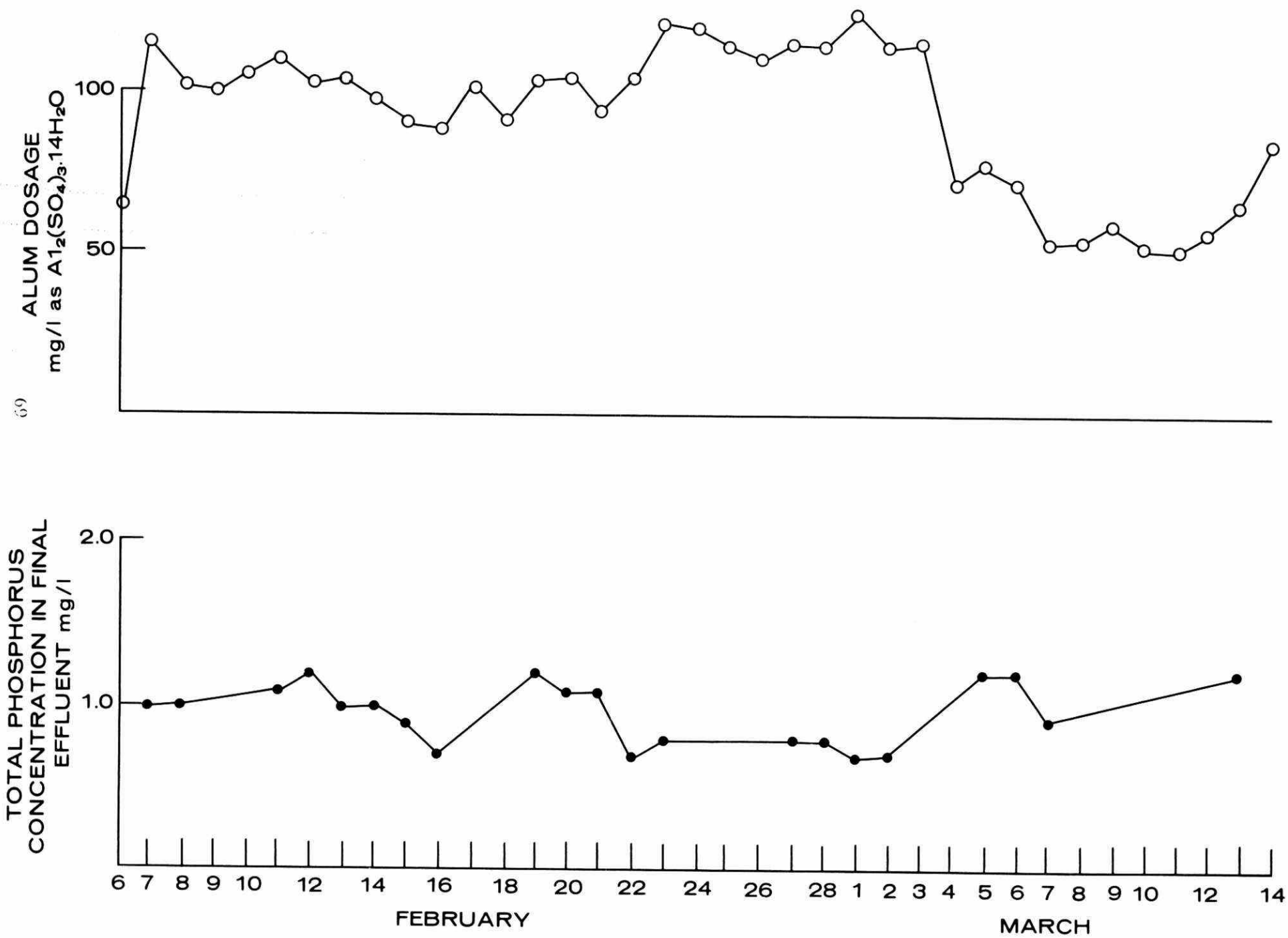

ALUM DOSAGE
mg/l as $Al_2(SO_4)_3.14H_2O$
100
50
TOTAL PHOSPHORUS CONCENTRATION IN FINAL EFFLUENT mg/l
2.0
1.0
6 7 8 9 10 12 14 16 18 20 22 24 26 28 1 2 3 4 5 6 7 8 9 10 12 14
FEBRUARY
MARCH

FIGURE 42 TOTAL PHOSPHORUS CONCENTRATION IN FINAL EFFLUENT VERSUS ALUM DOSAGE (Based on daily average)

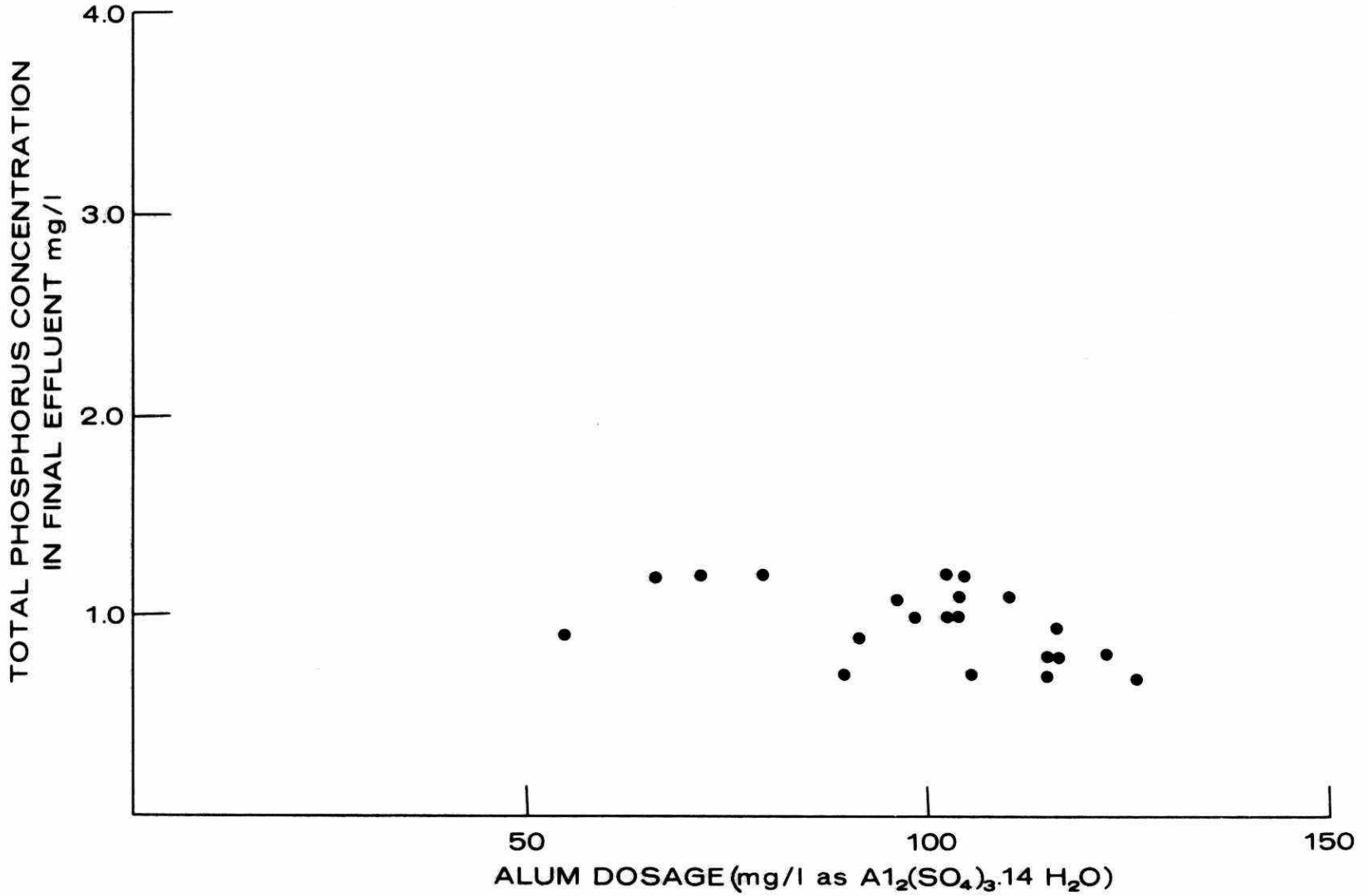


FIGURE 43A ALUMINUM TO PHOSPHORUS MOLAR RATIO REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL DISTRIBUTION IN ACTON RAW SEWAGE

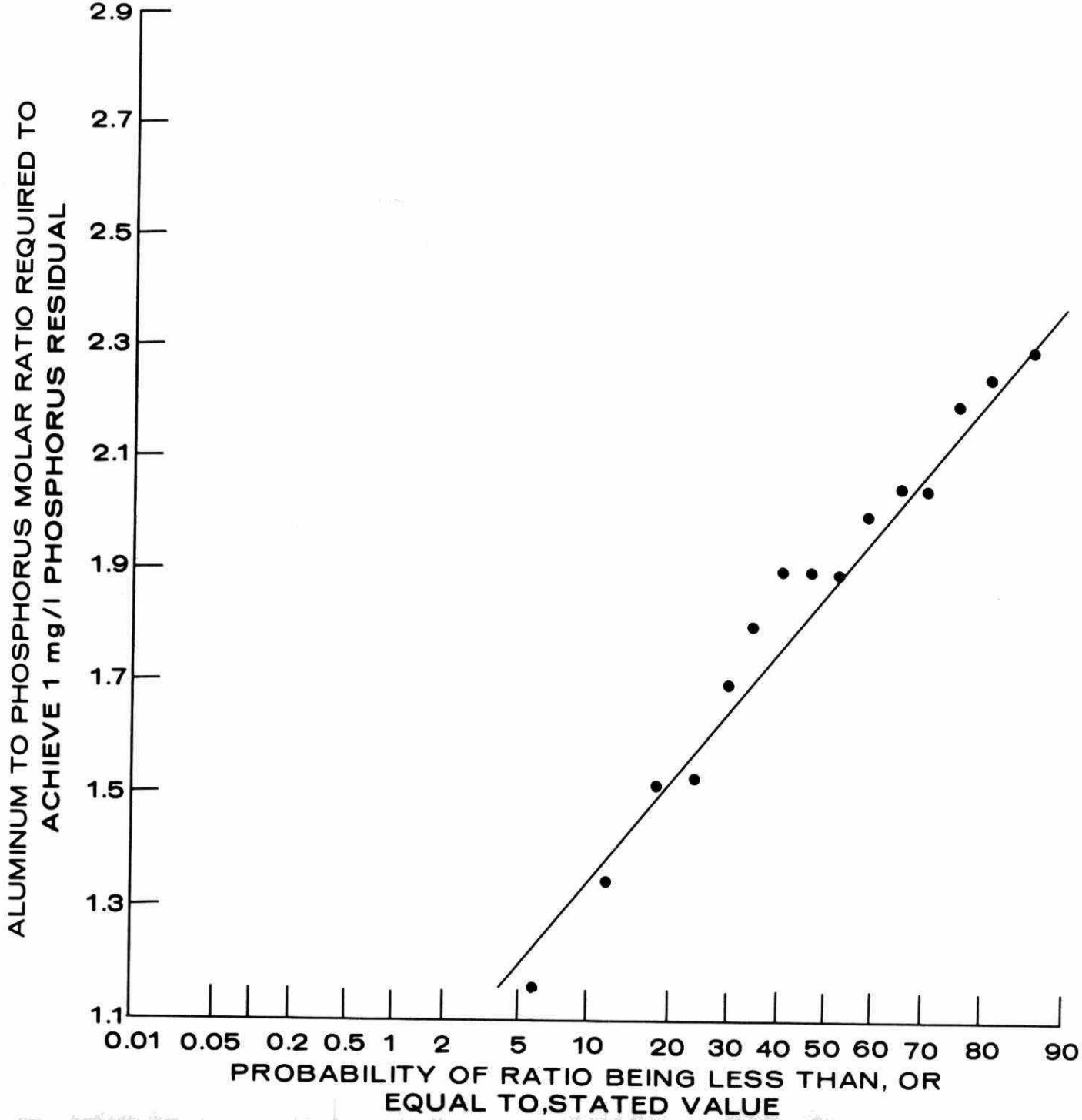
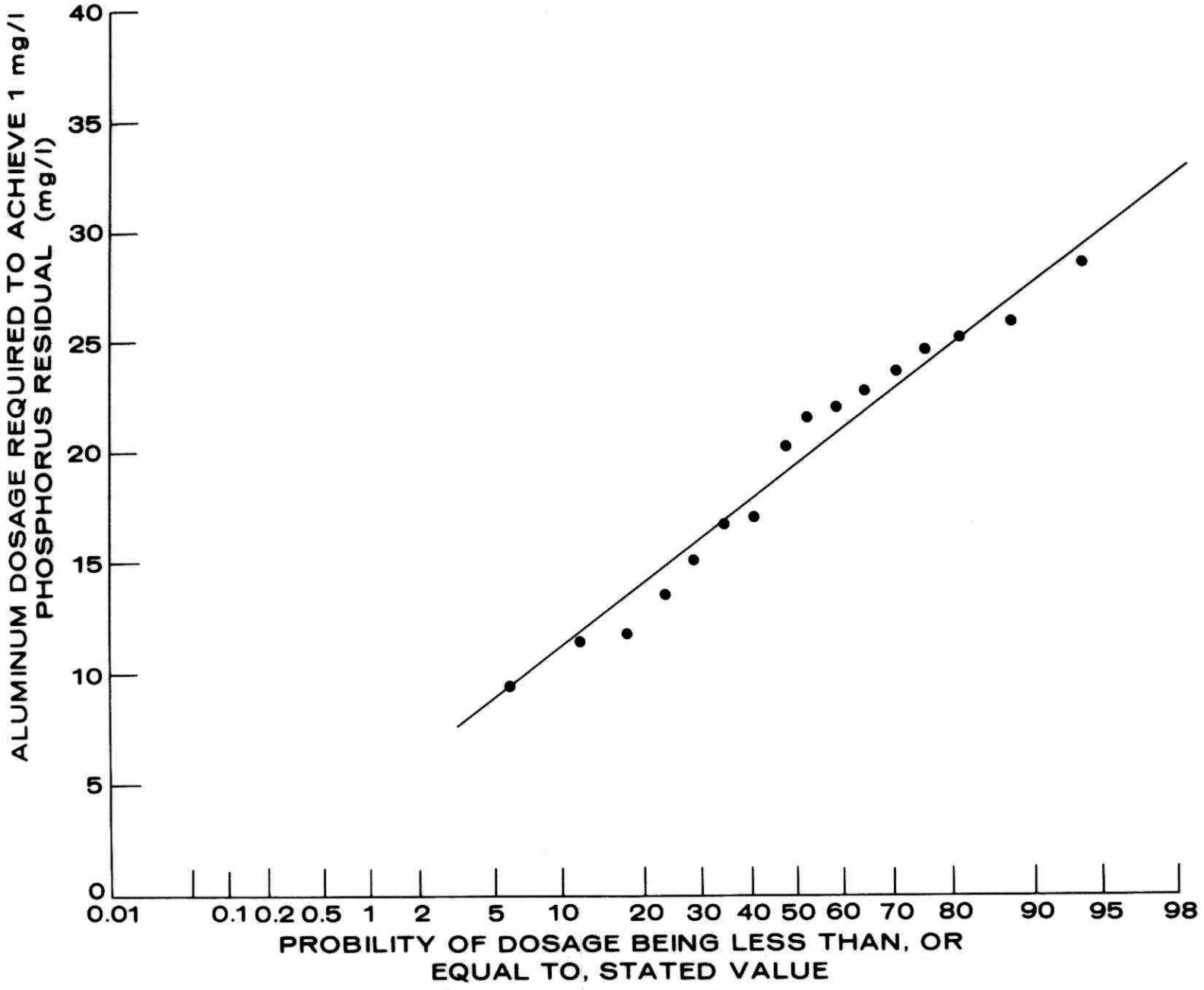


FIGURE 43B ALUMINUM DOSAGE REQUIRED TO ACHIEVE 1 mg/l PHOSPHORUS RESIDUAL - DISTRIBUTION FOR ACTON RAW SEWAGE



APPENDIX II

CALCULATION OF CHEMICAL REQUIREMENTS

APPENDIX II

CALCULATION OF CHEMICAL REQUIREMENTS

Figures A1, A2 show the distribution of aluminum dosage and aluminum to phosphorus ratio required to achieve 1 mg/l phosphorus residual in waste water samples. (The aluminum dosage required to achieve a 1 mg/l phosphorus residual was obtained by the procedure described in Section 3.2)

From these figures, it can be deduced that:

a) an aluminum dosage of 25 mg/l is required to achieve a mg/l phosphorus residual for 80% of the time and ;

b) a 2.2 :1 aluminum to phosphorus molar ration is required to achieve a 1 mg/l phosphorus residual for 80% of the time.

These values can be used to estimate relative chemical requirements for each of three dosing modes

MODE 1 - dosing proportional to waste water flow

MODE 2 - dosing proportional to product of waste water flow and phosphorus concentrations (equivalent to dosing at a constant Al: P ratio)

MODE 3 - perfect dosage control (at any time, just enough chemical is dosed to achieve a 1 ppm phosphorus residual)

Table A1 presents the details of these calculations.

TABLE A1. SAMPLE CALCULATION

Phosphorus concentration in wastewater before chemical addition (mg/l)	DOSING MODE 1 Amount of Aluminum to achieve 1 mg/l Phosphorus residual for 80% of time (mg/l)	DOSING MODE 2 Amount of Aluminum to achieve 1 mg/l Phosphorus resiudal at 2.2:1 Al:P ratio (mg/l)	DOSING MODE 3 Amount of Aluminum to Achieve 1 mg/l Phosphorus residual (as per jar tests) (mg/l)
15.5	25	29.7	15.53
8.0	25	15.3	9.48
8.72	25	16.7	11.5
10.6	25	20.3	17.4
7.6	25	14.6	13.6
15.2	25	29.1	25.1
15.3	25	29.3	23.8
15.5	25	29.7	22.9
12.5	25	23.9	21.8
14.7	25	28.2	24.6
8.9	25	16.9	11.9
Average	25	23.06	17.96
Relative Values	1.39	1.28	1.0

APPENDIX III

ANALYTICAL METHOD FOR PHOSPHORUS DETERMINATION

APPENDIX III

ANALYTICAL METHOD FOR PHOSPHORUS DETERMINATION

A. Determination of Total Phosphorus (acid-hydrolysable)

(1) A suitable aliquot of thoroughly mixed sample (depending on the expected phosphorus concentration) is measured out into a beaker and diluted to approximately 60 ml.

(2) 2 drops of phenolphthalein indicator are added. If red colour develops, strong acid solution (600 ml concentrated H_2SO_4 plus 4 ml concentrated HNO_3 diluted to 1 litre) is added to just discharge the colour. Boiling chips and an additional 0.5 ml of strong acid solution are added, and the beaker is covered with a watch glass and boiled for 90 minutes at $400^{\circ}F$. The volume of the solution is maintained between 30 and 60 ml.

(3) The boiled solution is cooled. NaOH of known normality (such as 6N) is added until the solution turns pink and it is then titrated with dilute H_2SO_4 until the colour is just eliminated.

(4) The neutralized solution is transferred quantitatively to a 100 ml volumetric flask and made up to volume.

(5) 4 ml of Ammonium Molybdate solution, (25gm$(NH_4)_6$ MO_7 $O_{24}\cdot 4H_2O$ plus 280 ml concentrated H_2SO_4 in 1 litre)and 6 drops Stannous Chloride solution, (2.5 gm $SnCl_2\cdot 2H_2O$ in 100 ml glycerol) are added and the colour developed for 10 minutes.

(6) The absorbance is read on a Spectrophotometer at a wave length of 690 mμ.

(7) The concentration of total phosphorus is read from the calibration curve.

B. Determination of Total Soluble Phosphorus (filtrable)

The sample is filtered through Cartorius membrane filters and a suitable aliquot of filtrate is taken for determination. Then the procedure outlined under A. is followed.

C. Determination of Ortho-Phosphorus

(1) A suitable aliquot of thoroughly mixed sample is measured out in 100 ml volumetric flask, pH adjusted to neutral, if necessary, and made up to volume.

(2) 4 ml of Ammonium Molybdate solution, (25 gm $(NH_4)6\ MO_7O_{24}\cdot 4H_2O$ plus 280 ml concentrated H_2SO_4 in 1 litre) and 6 drops Stannous Chloride solution, (2.5 gm $SnCl_2\cdot 2H_2O$ in 100 ml glycerol) are added and the colour developed for 10 min.

(3) The absorbance is read on a Spectrophotometer at a wave length of 690 m μ.

(4) The concentration of ortho phosphorus is read from the calibration curve.

Ronalds-Federated Ltd. OKT 3-1455

Cat. No.: En43-11/4

©
Information Canada
Ottawa, 1974

TD
758.5
.P56
C44
1974

Chemical dosage control for phosphorus removal /
78487